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PNEUMATIC CAISSONS FOR TALL BUILDINGS

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PART II

In the foregoing part of this article dealing with caisson construction we find there are two distinct bodies of concrete which are separated from each other by the wall of the shaft and the roof of the caisson. The roof is thought to be a serious matter, for, if it deteriorates, a settlement of one part of the composite pier is to be expected. The pneumatic procedure is usually adopted because of the presence of water, and whether the roof be of wood or steel, the action of water at a considerable depth is ordinarily regarded as a preservative one. However that may be, in New York especially, the tendency has been to get rid of it altogether. Quite recently, in the construction of the foundation piers for the tall building of the United States Express Company, there was put into practical effect the idea of eliminating the roof. The roof is only a temporary affair under the old conditions as well as these newer ones. The United States Express Co. building is the first case of the actual elimination of the roof. The shaft casing may also be removed but not the shaft lining as it must connect the air lock and the working chamber until the sinking is completed and the air pressure finally removed.

Fig. 6 is a sectional view of a typical pneumatic caisson, which has reached its final position with its cutting edge on the bed rock. Notice the heavy timbers of the working chamber. Sometimes the side walls have to be excessively thick and the roof thicker yet it is largely a question of the depth to be penetrated and the character of the soil. In the case shown in the figure, walls and roof are moderate. Above the caisson proper is the concrete surrounding the working shaft and enveloping this concrete is the cofferdam, which has been left in. The tube which conducts the air to the working chamber penetrates the concrete on the right. When the bottom has been properly cleaned off, and the sections of collapsible steel shafting have been removed, the working chamber and the shaft may be filled with concrete. If it is desired to tie the superstructure to the pier, it may be accomplished at this juncture—that is, before the final concreting.

It is not always necessary to carry the caisson to bed rock, even though the excavation for the pier is carried that far. Thus, at the Singer Building, the bed rock was overlaid by a stratum of hard pan and when the caisson had fairly entered this material, it could be stopped and the excavation completed without its use, but the concreting of the caisson and its shaft could, of course, not be done until the excavation was completed.

Calculating Strains

It is necessary to use considerable common sense and experience in attempting to calculate the strains in a caisson. As regards the

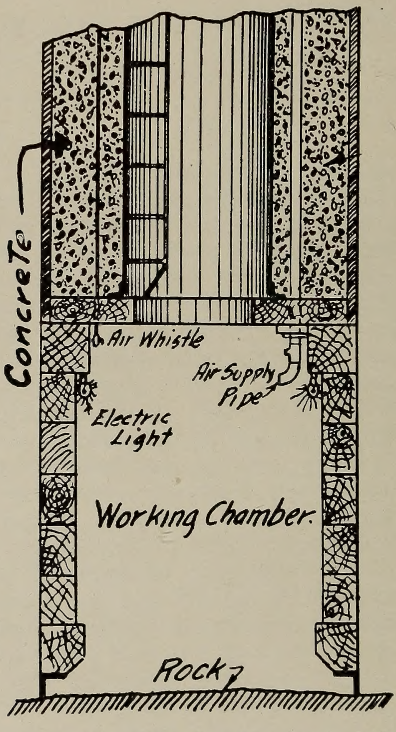

Fig. 6—Sectional View of Typical Pneumatic Caisson where Bed Rock has been reached by Cutting Edges.

deck, for example, it is very easy to calculate the weight to be carried by the deck and the strains that would result therefrom, and we know that the air pressure acting up against the roof will counterbalance a great deal of this weight, making it, in fact, something like a pontoon floating in water. But on the other hand, the air pressure is often slaked down to almost nothing in order to overcome the friction, and is raised again before much water has time to enter the working chamber; and sometimes an accident to the air plant

1 T. Kennard Thomson: *Pneumatic Caissons*,—"Construction," Toronto, Nov. 1908.

will suddenly cut off the supply of air, throwing a tremendous strain on the roof. If the principal weight on the roof is concrete it will in many cases be self-sustaining unless too fresh.

The same with the sides. If the material were absolutely homogeneous all round and the caisson were sunk absolutely plumb, which almost never happens, and the air pressure were kept just equal to the outside pressure, then we would have practically no strain on the sides; but all practical caisson men have seen the sides of caissons collapse, and some very strongly built ones at that. A very much more frequent cause of accident than loss of air pressure is to strike some obstruction on one side, deflecting the cutting edge, and thus throwing much of the weight of the caisson on the weakened side, making bad worse.

A caisson 8 feet wide has had its sides so distorted and compressed that there was not room left for a 29 inch bucket to enter the working chamber from the shaft. In this case the working chamber was made too light to start with, and collapses occurred in the working chamber, and a couple broke in two above the deck and had to be stopped where they were in the quicksand, some 20 feet above hardpan, and the excavation continued under the cutting edge by lining the sides, as in the case of a vertical tunnel—a very risky proceeding, but successfully accomplished.

Some caissons have been sunk as much as 5 feet out of plumb, an inexcusable state of affairs for a small caisson, for while we have said that very few caissons are absolutely plumb, still there is no excuse for their being more than a few inches out.

Large concrete steel caissons have been sunk and in one case it was claimed that by using reinforced concrete the company had saved $100,000, as compared with the cost of the steel caisson they had contemplated; but an equally large caisson, 46 x 130 feet of wood, the total cost of which would be only about $25,000 would have been possibly better. So if the cost of the reinforced concrete caisson were compared with a wooden caisson it would be rather difficult to show a saving of $100,000.

In building wooden caissons it is not best to halve the timbers or use dovetailed joints, but to use butt joints as much as possible with plenty of drift bolts. The trouble with butt joints, however, is that while a carpenter will make a dovetail or half-joint fit he will probably leave an inch or so play in a butt joint.

The deck timbers, as well as those in the sides, should be planed on one side and one edge, for the sides would otherwise vary too much to get a good job, while the planking for the outside and inside of the air chamber should be either tongue and groove, or the sides should be planed for a calking joint. The plank should, of course, have its faces also planed.

It is very important, and difficult, to keep the water out of the cofferdam, and it requires great care with the calking, for sometimes a joint under the cutting edge is not completely calked, with the result that the water finds its way up through the sides and into the roof or deck and thence through the concrete, forming a very bad

leak which it is impossible to stop, as its location cannot be discovered. This often necessitates continual pumping in the cofferdam while new concrete is being deposited, which is, to say the least, of no benefit to the concrete.

One of the most important contrivances on a pneumatic caisson is the air lock, without which the work cannot be carried on.

The Air Lock

The theory of the pneumatic caisson is of course, that an air pressure equal or slightly superior to that due to the head of water above the foot of the caisson will exclude the water and keep the interior dry, and this it does perfectly. If the shafts are left open the water will rise in the working chamber until no additional water can enter. If the strata to be gone through are perfectly impervious, the contained water can be pumped out and the caisson sunk by open air methods, and if but a small quantity of water enters, the pumps may, perhaps, be relied on to keep the interior in condition, but if air compressed to a tension constantly equal to the hydrostatic pressure is supplied in sufficient amount, then the work chamber can be kept quite free of water irrespective of the permeability of the soil, therefore, when the caisson has become well settled, the air locks can be added. The office of the air lock is quite analogous to that of the hydraulic lock on a canal. In the latter case, by the use of a lock-full of water from the supply at the upper level a ship is enabled to make the passage between the two levels. So with an air lock. It is a device which by the use of a lock-full of compressed air permits a person or load or empty bucket to pass to and fro between the working chamber and the external atmosphere. With the locks added and the compressed air turned on, the men are enabled to proceed with the excavation until the required level is reached. It is understood that the compressed air plant must continue at work for two reasons: to compensate for the loss of air occasioned every time the lock is used and also to increase the pressure as penetration to lower levels advances.

The air lock in general use in the United States is, fundamentally, it seems, the invention of D. E. Moran, Vice-President of the Foundation Company. He has improved his original device, so that now the Moran air lock can be operated, so it is claimed, with despatch and safety. While despatch is by no means to be sought while the men are passing through, it is of high value in making disposition of the spall.

By referring to Fig. 7, a view of this air lock will be seen in three different situations. Such a lock is fitted to the upper end of the working shaft. This union is made air-tight, of course. There are two horizontal doors, each of which may be swung downwards into a vertical position. The upper one of these closes the external entrance to the lock; the other a short distance below, when closed, completes a division of the total space subject to air pressure into two compartments. The upper compartment is quite small; the lower extends to the bottom of the working chamber. These doors

are both closed as shown by the top view. There is, however, a tubular connection between the two compartments, as may be seen in all the views. There is a three-way cock in this connection by which the upper and lower compartments may be put in communication or the upper may be opened to the external air. The conditions disclosed in the top view represent the situation immediately precedent to opening the upper door for entrance. The air pressure in the lock chamber is already at normal, or will soon become so by the equalization taking place.[1]

As soon as the air pressure in the lock falls to that of the outside atmosphere, the upward pressure against the upper door will be removed, and it may take the vertical position shown in the middle view. The empty bucket may now be introduced and by swinging this somewhat to the left the door may again be closed. If now you turn the three-way cock to cut off the lock chamber's connection with the external air and establish it with the lower compartment,

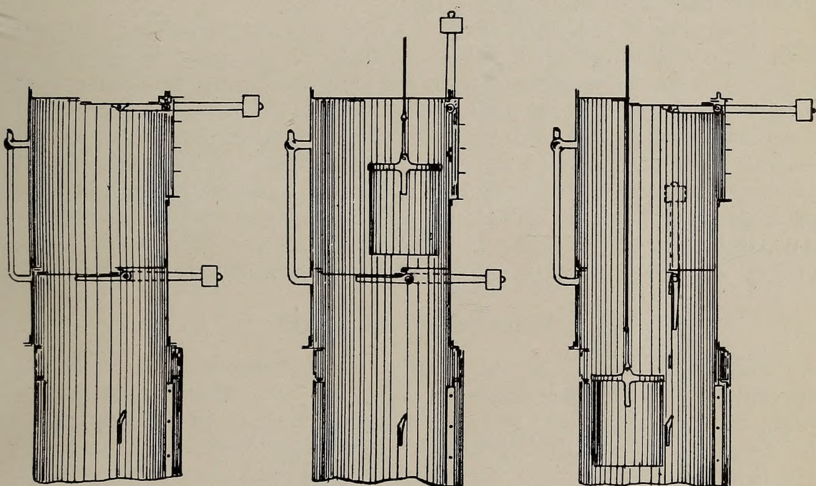

Fig. 7—Moran Air Lock in three different positions.

there will be an inrush of compressed air into the compartment, bringing the pressure there into equality with that below. The excess upward pressure against the lower door will now be removed, thus permitting the opening of it, which is the situation shown in the lower view, and the bucket may be lowered. There is a vertical separation of the shaft below the lock into two passage ways—one for the workmen, one for the material.

This seeks to avoid the danger of men being struck by passing buckets. In passing out, the three operations are gone through in reverse order. Thus the lower view may represent the bucket ascending into the lock chamber where the same air pressure exists and as soon as the bucket is well into this chamber, the lower door

1 Modern Steel Caissons. J. F. Stringer, Ir. Trd. Rev., Jan. 10, p. 101

may be closed and the cock turned and there will follow an equalization of pressure between the air in the lock chamber and the external atmosphere. This lock-full of compressed air will be lost, but no more, as the connection of the lower compartment is now cut off. The upper door may now be opened and the bucket withdrawn as shown in the central view, and if we now close the upper door, we have again the conditions represented in the upper view. It is sometimes necessary to adopt precautionary measures to prevent the workmen coming up from the heavy pressure of the working chamber from passing out of the lock too quickly. Thus, in building the foundations of the Clinton Bridge, where the pneumatic system was employed for part of the work, a regulating valve was employed. When the pressure was in the neighborhood of 35 pounds, corresponding to a depth of perhaps 75 feet below the water, the pressure of air in the lock chamber would not be allowed to fall to that of the outside air under 15 or 20 minutes, and there was thus allowed some time for nature to readjust matters.

A section of the shaft itself is sometimes converted into an air-lock by connecting two doors to it, but the specially designed air-lock which can be connected with the shaft at its top, bottom or any intermediate point is also used. The air lock at the top, being simply a section of the shaft is preferable, as any section can be converted into an air-lock, or the whole section if so desired. This arrangement possesses many conveniences, and it is much safer than when located at or near the bottom. The number of patents of air locks is numerous, but they are all after the same plan as the Moran Air Lock, and on the whole, it is probably the best and most universally used.

Removal of the Earth

The removal of the earth from the caisson is accomplished in several ways. (1) One device is the sand lift, which consists of a pipe, reaching from the working chamber to the surface controlled by a valve in the working chamber. The sand is heaped up around the lower end of the pipe, the valve opened, and the compressed air in the working chamber forces a continuous stream of air and sand up and out. Mud or semi-liquid soil may be removed by this means by immersing the lower end of the tube and opening the valve, but this method is most effective with sand. Although the sand-lift is efficient there are some objections to it.

(1). Forcing the sand out by the pressure in the caisson decreases the pressure, which causes the formation of vapors, so thick as to prevent the workmen from seeing.

(2). The diminished pressure allows the water to flow in under the cutting edge and (3) if there is much leakage, the air compressors are unable to supply the air fast enough. Notwithstanding these objections, it is largely used.

The mud pump is free from the above objections to the sand lift, and in mud or silt is more efficient than it. The mud pump is based upon the principle of the induced current, and this principle is utilized by discharging a stream of water with a high velocity on

the outside of a small pipe, which produces a partial vacuum in the latter, when the pressure of the air on the outside forces the mud through the small pipe and into the current of water by which the mud is carried away. Fig. 8 gives some idea of the mud pump now in use showing the direction of the water and material.

A screen is placed at the lower end to prevent any large material or sticks, etc., from entering.

The clay hoist is a device for hoisting material in a bucket by means of compressed air, and is particularly useful when excavating

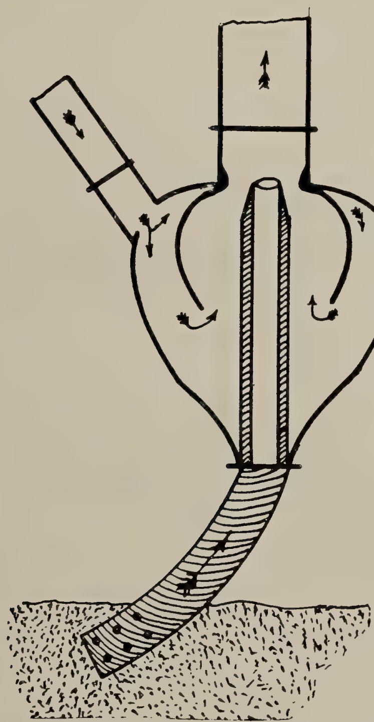

Fig. 8.—Mud or Sand Pump for removing material from working chambers

stiff clay, which cannot easily be removed with either the sand lift or the mud pump. It consists of a cylinder and piston placed at one side of the top of the material shaft.

The piston is actuated by air pressure, and is connected to a cable to which is attached a bucket working up and down through the material shaft. At the top of the shaft are two doors operated by levers from the outside, to facilitate the passage of the buckets. This device is very effective.

In making the excavation, the material should not be removed from under the shoulders until the middle space has been excavated to a depth of two or more feet below the cutting edge, so as not to

leave the caisson unsupported for any great length of time, and not at all under the lower side, if the caisson is out of level.

Sinking the Caisson

The only economical method of sinking is to have just sufficient weight so that the caisson will continue to move downward as fast as the cutting edge is undermined. Too much weight is obviously dangerous, as in soft material there is a risk of the cutting edge penetrating the material until the air chamber is filled with earth and water, and even if the men have all had time to escape it is expensive work digging in from the shaft to make room for the men and buckets.

The usual method, as Mr. Thomson describes, after a caisson has fairly started on its downward course, is to dig about a foot below the cutting edge, except just around the cutting edge itself, then removing the material directly under the cutting edge itself, and by slightly reducing the air pressure for a very short interval the net weight of the caisson and its load is increased enough to overcome the friction and to allow the cutting edge to reach the bottom of the excavation. In many places, however, it is impossible to keep the water level below the cutting edge, in which case it is not usual to excavate below the cutting edge.

When passing through hard material, such as hard pan, boulders, or rock, it is important to see that the excavation is made wide enough, or the caisson will surely become jammed. In fact, a 3-foot diameter cylindrical cast-iron underpinning caisson has become so jammed that four hydraulic jacks aggregating 320 tons would not bulge it, and as the jacks were acting against the wall of a building it was not considered safe to jack any more for fear of injuring the building that was being underpinned.

The proper form of cutting edge varies, but it and the sides should of course, be designed with the object of giving the maximum room to work at or under the cutting edge, for, at the best, removing the material at the cutting edge is very much more expensive than removing the rest of the material.

Advantage is often taken of the absences of the men from the working compartment to lower the air somewhat, which is equivalent to adding weight to the caisson and usually the structure sinks a short distance, and then the air pressure is restored again. It might be thought, perhaps, that the reduction of the pressure a few pounds could have no great effect, but if we consider this a moment, it will be evident that the air pressure is, ordinarily, assisting in the support of the structure, and this support is exerted over an area equivalent to a large diameter. The reduction of a single pound in the pressure is consequently equivalent to the addition of considerable weight, and it is easily seen, then, that the reduction of several pounds would have substantial effects. In certain pneumatic caisson work at New York, considerable reductions in pressure were made even with the men in the working chamber.

Of course, such an expedient would only be temporary, as the pressure was really required to overcome the hydrostatic head.

In using the pneumatic method, one has to overcome not only the skin friction between the surface of the caisson and the soil, which may amount to a great deal and varies, of course, with the character of the strata penetrated, but there is a very considerable resistance to penetration due to the pressure of the air that excludes the water, and as one goes down below the hydraulic level the pressure required to effect this exclusion constantly increases. As this pressure is exerted in all directions, upwards as well as downwards, and the resistance to penetration is that due to the total exposed area multiplied by the air pressure, which increases the hydrostatic head. Thus in sinking a caisson one must overcome with the weight of the caisson itself and its accessories, and with that of the load added, not only a skin friction that is becoming greater and greater, but also a constantly increasing thrust upward from the compressed air. In practice, it is often necessary to assist the augmenting load of concrete very considerably. To accomplish this extra loading with an economy of space, pig iron may be used, cast in such forms as to be convenient to handle. This may seem a trifling matter, but it is not to be so regarded. In putting down 116 piers for the new Municipal building in New York City, The Foundation Company used $25,000 worth of such weights. Not only is that amount of capital tied up by this one item, but it cannot be entirely recovered, because, to scrap the iron it must first be broken up which costs money. Thus it is evident that the proper sinking of the caisson is very important, because if it is not properly done, it may entail enormous expenditures.

Concreting the Working Chamber

The filling of the air chamber with concrete is an important proceeding. Bucket locks are much used for concreting the working chamber as well as for excavating small caissons, but for the large caissons or where there are two shafts, a special concrete lock is used. This is usually an ordinary three foot shaft with a door in the bottom and a cone above the lower door. The lock is placed on top of the shaft and has a hopper arranged over it. As soon as a yard or so of concrete has been dumped into the lock, the top door is shut and the bottom door is opened, allowing the mass to fall down the shaft into the working chamber. The concrete can thus be taken in about as fast as the men below signal that they are ready for it.

Concrete should be made very wet, wherever possible, but the men in the air chamber do not like it wet at all, and they are always asking for drier concrete. As long as the concrete is spread in approximately horizontal layers it cannot be too wet, but when it is necessary to bench it around the sides and under the roof it is impossible to use wet concrete. It is customary to fill the air chamber in horizontal layers within about three feet of the roof and then bench the concrete around the sides and under the deck until there is only a space under the shaft left. The men, of course, prefer,

where they can, to keep a working space about 5 feet high. The concrete is usually carried to within three or four inches of the roof, and the remaining space is then filled with mortar packed in place with a wooden rammer about one by three inches by three feet long, driven or pounded with an eight pound hammer, which gives a very good job, but is, of course, very slow.

Sometimes the concrete is carried up horizontally to within 18 inches of the deck and allowed to set hard, at least 12 hours being necessary, when the air is taken off and wet concrete is dumped down the shaft. The trouble with this method is to be sure that all the spaces under the roof get filled, for no one else who has not tried it would believe that the water in the concrete could disappear so completely. It has been seen in a caisson with two 3-foot shafts about 6 feet centre to centre, where the concrete was dumped down one shaft in an absolutely "sloppy condition," that when work was suspended to examine the concrete, it was found that the concrete was filling the shaft it was dumped into without filling the space under the deck to the adjoining shaft. Concrete has been dumped into a shaft so wet that one would expect to see a couple of feet of water on top of the concrete, and yet when the work was stopped the concrete looked almost dry.

If mortar is to be made watertight, the proportion should never be poorer than one volume of cement to two volumes sand, to insure filling all the voids in the sand. For the same reason the proportion of cement and sand should be the same for concrete where as much stone can be used as can be covered, depending on the smallness of the stone or gravel and the wetness of the mass; much more stone can be used if the stones are small and the mass wet. Caissons have been made watertight against a head of 80 feet of water by concreting to about 6 inches above the cutting edge and then placing a layer of mortar about 2 inches thick and covering this at once with good wet concrete 1-2-4. And yet many say that it is impossible to make concrete hold water, which, however, is certainly true as far as "dry" concrete is concerned, that is, concrete that requires ramming to bring the moisture to the surface.

The concrete in the cofferdam above the deck should also be put in very wet, and though it is very customary to use 1-3-5 concrete for this purpose, it is preferable to use a 1-2-4 mixture, though the amount of stone could be increased as stated above if judgment is used.

Great care should always be exercised when pumping is necessary to avoid pumping the cement out of the concrete and thus ruining the mass. The amount of concrete placed on the deck of the caisson while sinking often depends on the amount of weight required for the penetration. The friction on the sides starts at the surface and the concrete on the deck has to be kept above the surface of the ground until all the concrete is in that will be required for the finished structure, when pig iron or other temporary weight has to be added.

Caisson Disease[1]

When a novice enters an air lock the pressure is, of course, at atmosphere, and as soon as the outer door is shut (it is usually held shut by the pressure of the air) the pressure is gradually increased; but no matter how slowly it is increased, one has, at first, more or less trouble in equalizing the pressure on both sides of the ear drums. This is usually accomplished by closing the nostrils with a finger and thumb and then blowing the air through the throat into the ear passages. Sometimes beginners cannot do this, and occasionally even an old timer will get caught this way if he happens to have a bad cold.

The result of getting "blocked" is that one or both ear drums may be ruptured, causing intense pain, or some blood vessel in the head may burst.

The most common complaint is known as the "bends" which only attacks one after leaving the caisson, sometimes several hours after, and thus tends to bear out the theory that caisson disease is caused by the air forcing the blood away from the surface and the bubbles of air remaining in the system when the person has left the air chamber too quickly.

The bends generally attack the arms or legs, and sometimes the lower part of the body, causing more or less intense neuralgic pains or cramps, which are said to resemble rheumatism, but to be worse. Yet, in spite of the intense pain and suffering, they rarely result in death.

The worst effect, however, is paralysis, which attacks the limbs or body, though generally the legs or lower part of the body.

Sometimes the victim becomes paralyzed on the whole of one side. This trouble also, as a rule, attacks the unfortunate man shortly after he has left the compressed air, though sometimes not for several hours after. It is very rare for a man to be paralyzed while in the air chamber, though some have been killed the first time they have entered, and before they could get out.

Occasionally an old-timer, who has always considered himself immune, has been bowled over. When paralyzed, some completely recover after a few hours' treatment, some remain partly maimed for life, while others succumb as a result. Some experienced men claim that they can tell when they are going to get the bends or be paralyzed while still under compression, in spite of the assertion of other writers and experimenters that all forms of caisson disease are contracted during decompression.

Forty-five or fifty pounds above atmosphere is about the limit in which men have performed actual work, and these high pressures are always attended with great risk and loss of life.

There are a number of theories advanced, and there is much in all of them concerning the cause of caisson disease, from which the following established facts can be set down.

(1) The more rapidly one enters the high pressures, the more

T Kennard Thompson—Sc. Am. Supp. Oct. 17—08.

rapidly the blood is forced from the surface, and the greater risk of bursting blood vessels in the head or of fracturing ear drums.

(2) The longer one stays in compression and the more work that is done, the greater the danger of being paralyzed or of getting the bends.

(3) The quicker the pressure is reduced on leaving the caisson, the greater the danger.

(4) In many cases foul air has done more damage than fresh air at a much higher pressure. Undoubtedly, tallow candles in the early caissons, and gas in the Brooklyn Bridge caissons, did much to knock the men out.

(5) It is very dangerous to enter a compressed air chamber with an empty stomach.

(6) It is advisable to put on warm clothing and take hot coffee on coming out if there is any danger of getting chilled.

(7) The more energy expended in compression, the greater the danger. We know that the excess of oxygen in the compressed air renders the men very much more active than when in ordinary atmosphere, with a consequently greater fatigue.

(8) It is suicidal for anyone with weak lungs, heart or nerves to enter the lock.

(9) Even healthy people cannot be sure what effect compression will have on them until they try it.

(10) The most reliable remedy is recompression in a hospital lock.

(11) Electrical treatment is sometimes efficacious.

(12) Most important of all, as much time as possible should be taken in decompression—the more, the safer.

It has been found from experience that the same remedy will not always have the same effect on the same man; for instance, after suffering from the bends for several hours, it was found that a hot cup of coffee produced a profuse perspiration and relieved the pain, which, however, quickly returned; so a very hot bath was tried, which also banished the pain until the bath room was left behind. Then complete relief was obtained from a mild electric shock. Another time the electric battery was tried by the same person at once and failed to do any good.

In excavating there is always considerable escape of air under the cutting edge, etc., which, of course, has to be replaced by fresh compressed air, which keeps the atmosphere in the working chamber in a fairly good condition, whereas, when concreting after the concrete has covered the bottom above the cutting edge the loss of air is very much less, and hence less fresh air is received from the compresor, and the air becomes more and more contaminated as the concrete proceeds and the working chamber contracts, with greater danger of bends and paralysis. Sometimes, old-timers have gone in to uncouple bolts in the upper sections of the shaft, and in a short time have been taken out dead.

In one case, a rubber pipe caught fire and the compression pump-

ed the stifling fumes of burnt rubber into the working chamber, from which the men were with difficulty rescued.

When blasting in the working chamber, it is usual for the men to go out; but in one case where the working chamber consisted of several compartments the men walked into an adjoining compartment, out of the reach of any flying stones, etc., and after one of the discharges, one of the number was taken out dead.

Thus it is shown that application of compressed air underground has not only called into being a new type of man, "the sand hog" (the term applied to the man who works in the air chamber) but it has created a disease.

Regulations

For a number of years past there has been in France an effort to minimize the risks to which compressed air workers are exposed by the formulation of a code of rules and regulations governing all work carried on under pressure. The following notes serve to indicate the scope of the regulations now in force.[1]

It is stipulated that a physician shall be employed and shall have charge of the medical supervision of the men; before a man may enter the air he must present a certificate, issued by a physician, establishing his fitness for this kind of work. No man may be retained for work in air if his certificate is not renewed 15 days after employment and thereafter once a month. Provision is made for examining any workman who experiences trouble with nose, throat, or ears, or any man who desires to be so examined. An individual record mentioning all accidents or cases of illness, even though slight, must be kept up to date for each member of the force. Measures must be taken to prevent the introduction of intoxicating liquors on the work; any workman in a state of drunkenness shall be kept away from the work for 24 hours.

The time for compression shall be at least 4 min. when increasing from 1 to 2 kg. per square centimeter, total effective pressure, and at least 5 min. for each kilogram above 2 kg. per sq. centimeter (a pressure of 1 kg. per sq. centimeter is slightly less than one atmosphere being about 14.22 lbs. per sq. inch.)

The time for decompression shall not be less than indicated below; 20 min. per kilogram for pressures above 3 kg. per sq. centimeter, effective pressure, 15 min. per kilogram for pressures between 3 and 2 kg. per sq. centimeter, effective pressures, 10 min. per kilogram for pressures from 2 kg. down to an effective pressure of zero.

If the effective pressure does not exceed 1 kg. per sq. centimeter, the time to decompress down to zero may be reduced to 5 min.

It is forbidden to lower a caisson by suddenly reducing the pressure in the working chamber without first taking out the men.

Every lock must be fitted with a pressure gauge. If the effective pressure exceeds 1 kg. per sq. centimeter a recording gauge must be provided.

The height of the working chamber must be sufficient to allow

1 Regulation of Compressed Air Work in France, Eng. Rec., Dec. 4, 1909.

a workman to stand within it, in any case the height shall not be less than about 5 feet 11 inches.

The quantity of air supplied to the working chamber shall be at least about 1412 cub. ft. per hour per man. Carbonic acid gas shall not exceed one part in 1000.

In case the air supply shall be cut off the contractor shall order his men out of the working chamber after waiting for a period of 10 min. at the most.

It is forbidden to blast in the working chamber unless the workmen have left it and they shall not re-enter until the atmosphere within has become normal. (This measure does not prevent the men from seeking refuge in the shaft or locks.)

The volume of air in the lock shall be at least about 21 cub. ft. per man. The renewal of air in locks during periods of decompression exceeding 10 min. shall be assured by opening simultaneously, inlet and outlet valves thus allowing a flow of air through the lock.

In summer locks exposed to the sun shall be protected by a tent or matting kept wet.

When the work requires more than 20 men in the air at one time, communication between the working chamber and the surface shall be provided for by telephone.

Special precautions should be taken to prevent, in case of an attack of giddiness, a man's falling at the entrance to the lock.

Provision is also made for controlling entrance to and exit from the air from both the high and low pressure sides. The shaft should be accessible at all times and ladders maintained in it.

Equipment must be provided for taking out of workmen if they are unable to climb the ladders. The air lock, shafts and working chamber shall be illuminated by electric lights.

Precautions shall be taken in the working chamber to prevent workmen from passing underneath the shafts.

Each air pipe shall be fitted with a check valve, which will close when the pressure in the working chamber exceeds that in the pipe.

Automatic regulation of the pressure of air sent into the caisson should be provided for.

An outfit for affording aid to the injured shall be kept on hand; it shall include a tank of oxygen under pressure or other means of supplying quickly and easily a supply of oxygen.

When the work is carried on under an effective pressure of more than 1.2 kg. per sq. centimeter, a house, where the men coming from the air may rest, shall be built near the entrance to the work; its dimensions shall depend upon the number of workmen working simultaneously in the compressed air. It shall be suitably ventilated and fitted with wash stands, soap and towels for each workman, dressing room and couches.

When the pressure in the working chamber exceeds 2 kg. per sq. centimeter there must be installed a hospital lock containing a bed and large enough to receive 2 attendants.

All equipment such as machinery, pipe valves, ladders and cables must be tested weekly.

The joining of successive sections of the caissons shaft must be rigidly inspected.

Under certain conditions the regulations regarding the recording gauge, the maximum amount of carbonic acid gas, the telephone, the automatic regulation of the air pressure and the hospital lock, may be modified; in the last case, the physician must be consulted.

Compressed air workers must be at least 18 years old. These rules must be posted conspicuously. If these regulations were observed strictly in all casison or compressed air work, no doubt the number of fatalities and cases of caisson disease would be greatly lessoned.

Conclusion

Except in very shallow water or very deep water, the compressed air process has almost entirely superseded all others. The following are some of the advantages of this method.[1]

1. It is reliable, since there is no danger of the caissons being stopped, before reaching the desired depth, by sunken logs, boulders, etc., or by excessive friction, as in dredging through tubes or shafts in cribs.
2. It can be used regardless of the kind of soil overlying the rock or ultimate foundation.
3. It is comparatively rapid, since the sinking of the caisson and the building up of the pier go on at the same time.
4. It is comparatively economical, since the weight added in sinking is a part of the foundation and is permanent, and the removal of the material by blowing out or by pumping is as uniform and rapid at one depth as at another—the cost only being increased somewhat by the greater depth.
5. This method allows ample opportunity to examine the ultimate foundations, to level the bottom, and to remove any disintegrated rock.
6. Since the rock can be laid bare and be thoroughly washed, the concrete can be commenced upon a perfectly clean surface; and hence there need be no question as to the stability of the foundation.

A few years ago it would have been impossible to erect a building as lofty as are now erected upon the same sites without surrendering so much of the lower floors to caring for the foundations load as to render them practically untenantable. A cantilever system has been so thoroughly worked out in all its details during the past few years that although at some places and columns of a building are outside of the outside edges of the respective caissons, the load they bear is transferred by means of the cantilevers and bolster shoes so as to be evenly distributed over the base of the piers formed by these caissons.

After the caisson has reached bed rock and the chamber at the bottom and also the shaft is filled with concrete it becomes a solid monolith. On these monoliths the modern skyscraper rises.

1 Treatise on Masonry Construction. Baker, page 306.

CONCERNING THE HUDSON BAY ROUTE

By William Batten McPherson, B.A.Sc.

For more than twenty years the people of Western Canada have endeavored to persuade the Government to construct a line of railway to Hudson Bay from some point in Manitoba, and to erect proper terminals and docks at either Port Churchill or Port Nelson, believing that the move would render communication between the Western Provinces and Europe many hundred miles shorter than by the present Atlantic ports. These people realized that Canada would be faced by even more serious transportation congestion than the United States had been. To-day it is imperative that Canada should have as direct, open and rapid transportation with Europe as is possible. We are a nation in the midst of an enormous constructive period in which our imports annually exceed our experts by many millions of dollars. Imports that do not adjust or create debts must be paid for with exports. The faster this produce is laid down at tidewater, the greater its value to the Canadian producer and the better for the nation.

With the rapid and increasing growth of the Canadian West—Manitoba, Saskatchewan and Alberta—and the consequent enormous grain production, the necessity of creating an outlet for this production of our wheat fields and indeed for the other natural resources of north-western Canada has become a matter of serious import.

The cultivable area in the provinces named has been conservatively estimated at 175,000,000 acres, and while it would be hazardous to count upon the uncultivated portion being as fertile as that which has already come under the plough, it is believed to be safe to reckon upon its production in at least the ratio of one to two, so that we can reasonably count on ten times the present grain yield of these provinces when all the now virgin soil is brought under cultivation; and the wheat produced will amount to 1,000,000,000 bushels a year. This, with other crops, will bring the total to 2,000,000,000 bushels a year.

With the extension of the grain growing area the difficulty of transportation has increased enormously. Since 1896 there has been a continual grain blockade to such an extent that neither the outgoing grain nor the incoming freight could be handled by the railways with any reasonable dispatch. The condition to-day is that the crop of one year cannot be marketed before the crop of the next year is harvested.

Concurrently with the expansion of the grain-growing area. other industries have expanded in like ratio. Any arrest of Western development will be as keenly felt from the Atlantic to the Great Lakes as it will in the country beyond. Even though the double tracking of the Canadian Pacific and the inauguration of the Grand Trunk Pacific should double the rail-carrying power, the transportation problem would still be a larger difficulty in arrest of development that it is to-day.

Hudson Bay as the Outlet

A new outlet is to be opened. The present scheme of the Government consists in the building of 418 miles of railway from the Pas on the Saskatchewan, north-east of Lake Winnipeg, to the mouth of the Nelson River on Hudson Bay.

At the north of this enormous river the large docks and elevators are to be constructed to provide for loading grain and other produce for shipment to Europe. This port in the heart of Canada, in the meridian of the Mississippi, will undoubtedly become of immense importance.

The trunk lines of Canada have now more traffic than they can hope to handle expeditiously. Each year, even with increased mileage constructed, the glut is becoming worse. The Great Lakes route will always receive capacity in advance of terminal and ship facilities.

Fig. 1—The commencement of Port Nelson, unloading the first supplies, July, 1912

The eastern provinces are stretching out constantly demanding increased transportation. The Hudson Bay route—short rail haul—will do something to discount trouble in the future. The route over which Manitoba's early settlers arrived in 1811-12 and other years, will be given modern fittings. Many years ago a struggle of long duration took place chiefly throughout the western prairies and rocky mountains between the Hudson's Bay Company operating through Hudson Bay (York Factory) and the north west Company with headquarters in Montreal, both marketing their furs in London.

Eventually, in 1821, the Hudson's Bay Company was victorious because it was able to bring in its supplies and take out its furs cheaper and with greater despatch than its rivals. Hudson Bay navigation proved reliable then and ever since.

The following table serves to illustrate the saving in miles, considering distances from points in the west to tidewater at the Atlantic and Hudson Bay.

FROM	TO MONTREAL	TO PORT NELSON	SAVING
Winnipeg	1,422	885	537
Brandon	1,555	880	675
Regina	1,780	714	1066
Medicine Hat	2,080	1016	1064
Calgary	2,262	1194	1168
Prince Albert	1,958	667	1291
Battleford	1,994	816	1178
Saskatoon	1,924	746	1178
Edmonton	2,247	1069	1178

From these ports the sea voyage is:

From Montreal to Liverpool 2761 miles; from Port Nelson to Liverpool 2946 miles.

On its face therefore, there is an advantage of a saving of hundreds of miles by the Hudson Bay route. The other port of Churchill is about 200 miles north of the Nelson.

The country between the cities stated and the Port of Nelson is, comparatively speaking, level and free from engineering difficulties. Churchill has an excellent natural harbor, rock-enclosed, with a capacity for three or four dozen good-sized ships. It is 470 miles from the Western end of Hudson Strait. The Nelson, which is about the same distance from the Strait, possesses capacities of enlargement practically illimitable. A channel basin would require to be opened and the harbor would then accommodate innumerable ships. The channel at present existing is one which may with certainty be said to enable a ship drawing twenty feet of water to enter safely at all stages of the tide, and no doubt extended surveys will show more favorable conditions. Although discovered in the year 1610, and navigated at least once annually since 1667, Hudson Bay has remained an unknown sea, to the general public at least. It is the third largest enclosed marine area in the world, being exceeded by the Mediterranean and Carribean seas. The area is approximately five time the combined areas of our great lakes, and it has a tidal coast line of about six thousand miles. Into the Bay is discharged a score of magnificient rivers, some of which rank among the largest on the continent.

Hudson Strait, which is the chief connecting link between the Bay and the North Atlantic Ocean is 450 miles long and not less than 45 miles wide, with a deep clear channel. It is here that navigation is most likely to be delayed through the presence of ice which, in certain seasons, will probably always be an obstacle in the navigation of Hudson Strait, although a full knowledge of its character and movements will greatly reduce danger from such a source.

There are three classes of ice to be met with in and about the Strait, viz., icebergs, ordinary field ice, produced in the Bay and Strait, and Arctic ice. Numbers of the bergs may be seen in the Strait chiefly along the north side, but they will never be much source of worry owing to the width of the main channel. Twice as much difficulty is experienced in the Strait of Belle Isle owing to the narrow-

ness of the course. Nine-tenths of all bergs which enter the Straits gain access through Fox channel, where glaciers exist. The other source of icebergs is through Gabriel Channel, a connection between Davis Strait and Hudson Strait between Resolution Island and East Bluff. This channel has a strong polar current, but ice from this source is carried into the north Atlantic.

Field ice which, is rather local in formation, often attains five or eight feet in thickness, but becomes broken up into pans and ultimately melts. A great tidal wave from north Atlantic into Hudson Strait and through it into and across Hudson Bay affords an interesting study. That current is not as wide as the Strait, but on either side for miles there is an eddy created, which, running in a direction contrary to the main stream, has a peculiar and decided effect upon the floating ice. Its general effect is to keep the channel of the maincurrent open and to join it into the broad eddies along the shores. Hudson Bay and Strait do not freeze solid, but the floating ice would probably render them unnavigable for ordinary steamers for perhaps seven months in the year. June has well set in before much melting of the ice commences, and the middle of July would, as a rule, be reached before navigation became safe. In the autumn and until late in November, no ice is formed either in the Strait or Bay, sufficiently heavy to obstruct ordinary navigation. About this time there may be considerable danger from the passage of northern pack ice across the mouth of the Strait, and also to a much less degree, from the ice from Fox Channel partly closing the western entrance to the Strait.

Fogs are liable to occur in proximity to the ice fields particularly in the early season, but at other times are not prevalent and the weather is ordinarily fair. Ships go through ice to the harbors of Russia, Sweden, Germany and Norway every day of the Northern winter—specially constructed steamers in all probability—but they keep an open channel for the ships of commerce.

Hudson Strait

There are three entrances to Hudson Strait from the North Atlantic, viz., that between Cape Chidley and the Bulton Islands, five or six miles wide; the main channel, between those islands and Resolution Island, about forty-five miles wide, and that between Resolution and the north main coast, about ten miles wide. The first is called Grey Strait and the latter Gabriel Strait. These are the narrowest channels except at the western extremity where Nottingham, Salisbury and Mill Islands divide the strait into four channels. The main one, and that usually traveled between Nottingham and Cape Wolstenholme, or Cape Digges is about thirty-five or forty miles wide; that between Nottingham and Salisbury is not more than twelve miles wide; that between Salisbury and Mill about the same; and that between Mill and the north main coast (Fox Sand) probably fifteen miles.

Except at the points named and excepting also between North Bluff and Cape Prince of Wales, in the centre of the Strait where the

distance is about sixty-five miles, the width of Hudson Strait is over one hundred miles. At the entrance from the north Atlantic the water is very deep, over three hundred fathoms in the centre of the Strait. The shores on both sides throughout are high, rugged and barren with deep waters close to the cliffy, rock-bound coast. As you proceed westward toward Hudson Bay the water becomes shallower. The average depth of water in Hudson Bay is about eighty fathoms, except in the southern portion, where it does not much exceed sixty.

The distance from Cape Chidley, at the eastern end of the Strait, to Cape Digges at the western end, is about four hundred and fifty miles, the distance from Cape Digges across the Bay to Churchill or the mouth of the Nelson is not more than 550 miles. The total distance from Port Nelson to the north Atlantic does not exceed one thousand miles.

Hudson Strait and the centre and west of the Bay are free from shoals, rocks or islands and such impediments as are to be reckoned with on the St. Lawrence route, and from the Nelson River to Cape Chidley and the Atlantic Ocean there is not an obstruction or hindrance to navigation.

Navigability

After three centuries of exploration the navigability of Hudson Bay is, to most people, a vexed question. Sir Martin Frobisher first discovered Hudson Strait in July 1576, and two years later, with a fleet of fifteen vessels, sailed several days through it. He was in quest of ore. A number of years following this, expeditions visited Hudson Bay, which had been discovered in 1610 Most of these expeditions were in search of the north west passage. Since 1668 the Hudson Bay Company have used the Straits and Bay regularly, with singular good fortune, and remarkable freedom from wreck trouble. From 1670 until 1870, when Canada purchased the exclusive right of the Company, more than seven hundred and fifty vessels, ranging from seventy-gun ships to ten-ton pinnaces, crossed the ocean, passed through the Straits, and sailed the Bay in the service of the Company, and only two have been lost. These craft were sailers—most of them of rude construction—helpless when in ice where wind is usually deficient, sailing where no charts existed and using crude methods of navigation as compared with those of to-day. Navigation was good enough to admit the French several times and in 1782, La Perouse, the French Admiral, brought a seventy-four gun line of battleships, and two frigates of thirty-six guns each, to the mouth of the Nelson River.

From 1860 many American whalers have made annual trips into the Bay. The Hudson Bay Company has averaged two ships a year. The Canadian Government has sent many ships in and out of the Straits. This past summer saw the steamers Beothic, Stanley, Minto, Arctic and Nascopic come through the Straits to Churchill and the Nelson, and return later to their various ports without mishap.

As the charts of the Bay stand to-day, they are compilations largely from information supplied by various navigators as the result

of numerous trips; consequently accurate records are lacking. For many years—at least seventy-five—whalers and fishermen of the United States have visited the Bay with unusual success. United States statistics for a recent period of ten years show an average value of $30,000 per cargo, of more than fifty trips, of oil, fish and whalebone. Apart from showing value of fisheries it is significant of reasonable safety in these northern waters because these schooners from Massachusetts and Connecticut were not specially built. Several navigators of varied ice experience say that navigation of the Straits is safe for ordinary "tramp" steamers from the middle of July to the first of November, and possibly to the middle of that month. Mr. J. W. Tyrrell, an explorer of much varied experience in Hudson Bay says, "From my personal observation, I am of the opinion that for suitably constructed vessels, Hudson Straits are navigable for five months of the year—from the middle of June to the middle of November—with a possibility of an additional two weeks before and after these dates."

Land Approach to Port Nelson

In building the Hudson Bay railway from "the Pas" on the Saskatchewan to Port Nelson, a distance of 418 miles, no engineering difficulties are encountered. Already fifty miles have been graded and steel is now being laid. Seventy five miles more have been cleared and the contracts for the whole distance have been let.

The country through which this line runs contains innumerable lakes and streams which are bordered by areas of good timber varying from a few acres to some as large as forty or fifty square miles, and in the aggregate total several thousand square miles and of some commercial value.

A clay belt suitable for cultivation runs much farther north and east from the Saskatchewan than is generally believed. There are, of course, some stretches in this vast area which are swampy or semi-barren, but there is quite the average which obtains in Northern Ontario, while the climate is not so severe as to be prohibitory. The long summer days give more hours of sunshine than is the case in Southern Manitoba and Ontario, and consequently, crops can be ripened with no greater liability to failure from frosts than was experienced by the early settlers in Manitoba. There are very many large lakes, with sturgeon and whitefish, which will now be made accessible to the world's markets.

The first section of the railway is through a comparatively level country underlain by flat beds of limestone, affording easy grades and cheap construction, and where swamp is met a good bottom is usually to be had at from three to four feet. The Saskatchewan will require the only large bridge on this division.

The remaining section is underlain by granite in places, but the cutting will not be serious and the major portion of the grading is in clay loam. Economical ballast may be obtained and curvature will average $50^{\circ}30^{1}$ a mile over the whole route. A grade of .4 both ways

has been laid out. Altogether there will be three important bridges, namely the Saskatchewan crossing, another at Manitou rapids on the Nelson and the third at Kettle rapids which is also on the Nelson. Timber for the remainder of light bridging and for piles may be obtained over most of the distance to the Port.

The cost of the Railway complete with equipment and with a modern harbor and terminals has been estimated to amount to $25,000,000.

The Port

Port Nelson is at the mouth of the Nelson River, which is about the size of the St. Lawrence at Brockville, its discharge being close to 200,000 cubic feet per second. It carries the drainage waters of a continent, being the outlet of Lake Winnipeg, which, in turn, is fed

Fig. 2—York Factory, near Port Nelson, Hudson Bay.

by the Saskatchewan, rising in the Rockies, and the Red which rises in Minnesota.

The river mouth is a mile and a half wide at Seal Island opposite Flamborough Head, at the head of tide water and ten miles in width opposite Beacon Point which is twenty miles or so below.

The location of the docks and terminals will probably be some ten miles below Flamborough Head at a point where the river is three miles or more in width at high tide. At low tide quite extensive flats are exposed. Tides vary, running from 11 to 17 feet.

On the ebb tide the current flows about three miles an hour, increasing abreast of Beacon Point to probably six miles an hour. So great is the discharge of the river that a perceptible current may be noticed several miles out to sea. Tide readings are being taken regularly every ten minutes day and night in order to prepare accurate tables. Salt water does not come above Beacon Point.

By the 20th of December, the river is usually frozen over at head of tide and the ice gradually creeps down the

estuary. This ice usually goes out about the middle of May. Tide action soon breaks up the large floes and the current is sufficient to keep them from returning to the river.

Being some ten miles from the mouth of the channel, the anchorage will be protected from serious sea by shoal water and the roadstead will probably resemble that of Quebec in the matter of exposure to stormy weather.

The river bottom is a bluish clay with occasional pockets of coarse sand with boulders scattered through it, and is stiff, affording excellent holding material for anchorage. The material on the flats is sometimes spongy on the surface but is hard underneath. Much stone for construction can be quarried some miles above Flamborough Head—some also can be obtained from the flats. Spruce is the only timber here, but may be found probably large enough for piling.

Electrical power can be developed in plenty throughout the adjacent country. The Commission of Conservation report on the waterpowers available on the Nelson River as follows:

Site	Approximate Head in feet	Estimated Horse Power
Limestone Rapid	85	1,400,000
Long Spruce Rapid	85	1,400,000
Kettle Rapid	96	1,290,000
Birthday Rapid	24	320,000
Gull Rapid	67	900,000
Grand Rapid	20	270,000
Rapids above Sepewesk Lake	31	416,000
Bladder Rapid	10.6	147,000
Whitemud Falls	30	403,000
Ebb and Flow Rapid	11	148,000
Rapids above Cross Lake	45	605,000

The drainage area of the Nelson River is given at about 430,000 square miles, the estimated horse power is based on a flow of 118,000 cubic feet per second, taken when the river was at low stage. With these many power sites scattered along the length of the Railway electrification could easily be adopted. There are, of course, other power sites on the Hayes River, but these are not as accessible to the line.

During the past summer a party of thirty engineers and men arrived at Port Nelson by the steamer "Beothic" bringing materials for camp buildings and two years' complete supplies. Their work will consist in studying conditions, taking soundings and so on, to be followed immediately by actual construction.

For the past two years parties have been engaged in chart work off the mouth of the river—the C. G. S. "Minto" spending the summer of 1912 there. The "Arctic" was in the Bay and Straits all summer on magnetic work. There are many matters in connection with this new route which will be cleared up satisfactorily at an early date. It is said that insurance, which is extremely high for the St.

Lawrence route will be exorbitant for Hudson Bay. However, if it is demonstrated that for four or five months risks are at all reasonable, insurance will be satisfactorily adjusted.

Many anticipate difficulty in obtaining enough suitable ships to take advantage of the four or five months of navigation annually, but if business is plentiful, boats will be forthcoming.

There will be large and important industries opened within the next few years in Hudson Bay. For the past seventy years whalers have been visiting this territory from the Atlantic coast of the United States. Their schooners total $100,000 annually. Scotch whalers from Dundee also pay regular visits . The whales from Hudson Bay are worth from $10,000 to $20,000 apiece. In 1886 Lieut. A. R. Gordon gives the average value of each whaling cargo from the year 1846-1875 at $46,000 and Mr. A. P. Low in 1904, using information supplied by Captain Comer, an American whaler, places the average value of a whaling cargo between 1891 and 1904 at about $35,000. It is easily seen that this industry should be valuable to Canada. These fisheries are vast and varied. Bowhead or Arctic whales are worth $14,000 a ton and an adult whale will yield 1,500 pounds of oil and bone. Then the porpoise or white whale is present at the mouths of all the large rivers in thousands. These whales are about fourteen feet long and are valuable for their hide and oil. The walrus, is very common, in the northerly and westerly portions of the Bay and has a considerable commercial value. Several varieties of seal exist in great plenty. Salmon and cod swarm the waters. The salmon is so abundant and of such quality that an industry like that of British Columbia may be opened up. The Hudson Bay Company make annual shipments to Europe at present from Ungava Bay on the south side of the Strait.

It is easily seen that this new route will, in the next few years, show what exists in this region of Canada to be added to our reserve of natural resources. The rocks over much of the bordering region give promise of mineral wealth. Enough exploration has been done to hold great attraction to the prospector. However, apart from the latent resources of the Bay, this new route means much to the West. At half a cent per ton mile, it means fifteen cents saved for each bushel on the whole trip. When a crop of 60,000,000 bushels is laid down annually via the Hudson Bay Railway, the saving will be $9,000,000, which is seriously worth something to the producer. Once grain commences pouring out this way the ships will soon appear with west bound cargoes in return. On the shipping of cattle a saving of at least $5.00 to $6.00 per head will be effected in freight; considerable loss due to shrinkage which occurs when animals are confined on a transcontinental rail haul will be avoided, and the animals will be marketed in better condition.

In conclusion, the route is commercially feasible; the country exploited will furnish a good deal of wealth to the Dominion; the waters will yield much to our people; a large tract of land eminently fitted for settlement will be opened up; an additional outlet will be

provided for the west, and simultaneously we will have a new entrance to Canada. The question is truly national.

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THE DEVELOPMENT OF THE RE-ACTION STEAM TURBINE

BY J. A. MACMURCHY, '96.

We do not know when or by whom the steam turbine was invented, but it was probably the earliest form of steam engine. It is known to have been used two thousand years ago, and strange to say, at even this time both types—impulse and re-action, had been invented. At this very early day the application of the turbine was extremely limited because there was not then in use any machinery which needed to be driven at the extremely high speeds of revolution which are necessary to permit of its use. With the introduction of electrical machinery, however, a possible field was opened for a high speed prime mover, and in 1884 Mr. C. A. Parsons, of Newcastle, England, invented a form of turbine involving the re-action principle, and entered into partnership with Messrs. Clarke & Chapman, with a view to manufacturing steam turbines, and the electric generators which they were to drive. Many mechanical difficulties were encountered, making it necessary to do a great deal of experimenting, and it was unfortunate for Mr. Parsons that there was no market at that time for units of large capacity, consequently, he had to struggle with the manufacture of machines of capacities which were least suited to the type of turbine which he had invented. The first unit built was of about 6 h.p. In 1889 the partnership with Messrs.

Clarke & Chapman was dissolved, and Mr. Parsons lost the control of his patents for the time being. During the next few years he did an enormous amount of experimenting with other forms of turbines, particularly the radial flow re-action turbine, but without any par-

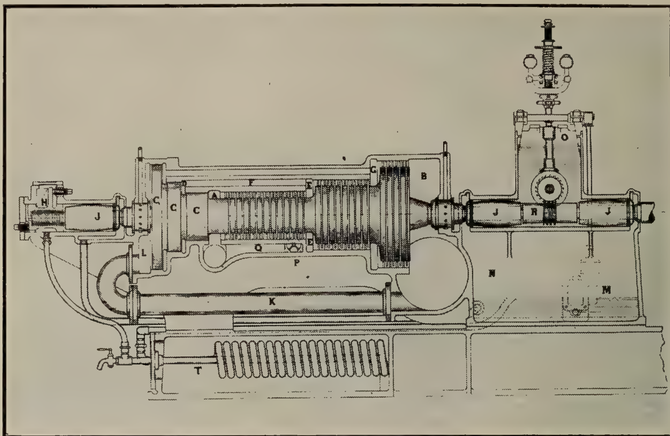

Fig. 1—Section through 400 KW. steam turbine built in 1900

ticular success, except to considerably broaden his knowledge of the subject. In 1894 he regained control of his original patents and from that time on, the development of the parallel flow re-action type

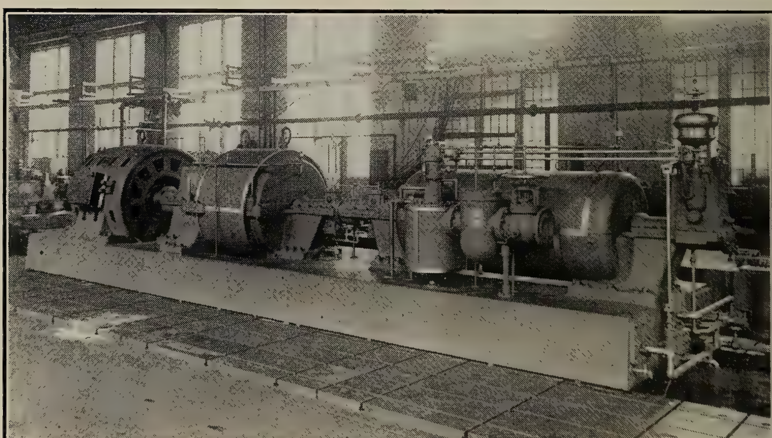

Fig. 2—Two-cylinder, 1,000 KW. steam turbines built in 1902

of turbine, which has now come to be best known as the Parsons turbine, was very rapid. In 1896 The Westinghouse Machine Company of Pittsburg, purchased from Mr. Parsons the patent

rights to build this type of turbine in America for land purposes, and Mr. Francis Hodgkinson, who had been associated with Mr. Parsons for some time, was employed to develop the turbine on this continent. After assuring themselves that their turbines were suitable for service, a number of the machines of the form shown in Fig. 1, were built, the first three being furnished the Westinghouse Air Brake Co. in 1899. These turbines were of 400 K.W. capacity, and were used to drive alternating current generators, the speed being 3600 R. P. M. From the first day they were remarkably successful, and more than fifty of this design were built. Later experience with turbines in service, particularly with superheated steam, indicated the desirability of a number of changes which were incorporated in the later designs.

The most serious defect in the early designs was in the use of the deep longitudinal ribs on the stator which seemed to be needed to give

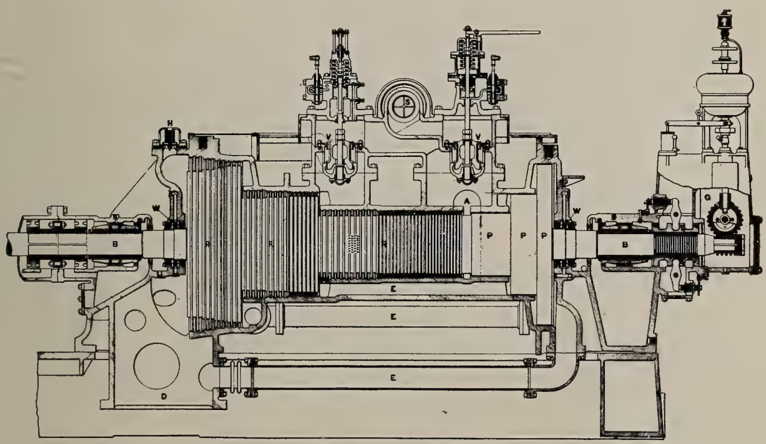

Fig. 3—Section through 1,000 KW. turbine built in 1904

stiffness and to preserve the alignment of the machine. It was found, however, that while these ribs gave very little trouble with machines using saturated steam, yet when used with superheated steam the centre line of the cylinder would warp due to the portion of the rib which was in contact with the hot steam expanding more than the lower portion of the rib which was exposed to the atmosphere and remained much cooler. For the same reason, the equilibrium passages which were cast integral with the cylinder casting were objectionable. Difficulty was also experienced with the glands, consisting of two groups of snap rings, with steam slightly above atmospheric pressure admitted in the space between to make sure that any leak would be a leak of steam outward into the engine room rather than a leak of air into the turbine cylinder. There was little difficulty in making these glands tight and they absorbed very little power, but the disadvantage was that they wore out in a few months, and, although the cost of replacing the rings was small, the necessity

of opening the cylinder to replace the rings was very objectionable, and the desirability of inventing some other form of gland became apparent.

In 1902 turbines were built on this continent in two cylinders connected in tandem, Fig. 2; the high pressure cylinder expanding steam from boiler pressure to about atmospheric pressure and the other cylinder from this pressure to the vacuum obtainable in the condenser. The reason for the adoption of the two-cylinder type of turbine was that it was felt that there was a considerable loss of power inside the turbine cylinder due to the water of condensation in the steam being thrown out towards the tips of the moving blades by centrifugal force, and there forming an annulus of water through which the tips of the blades ploughed with sufficient friction to absorb much power. The steam in going from the high pressure cylinder

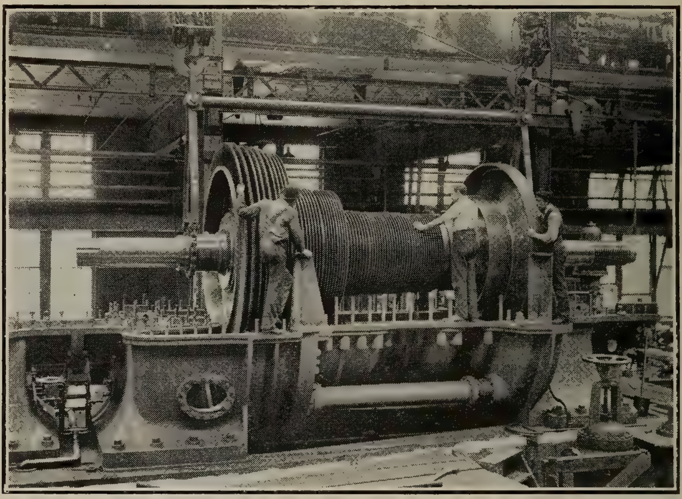

Fig. 4—View showing rotor of 7,500 KW. being lowered into casing

to the low pressure cylinder in these two cylinder turbines, passed through a receiver where practically all of the water was mechanically separated from the steam, and the steam was re-heated by passing it through tubes which were surrounded with high pressure steam, and, as a result, the steam entered the low pressure cylinder comparatively dry. Very good results were obtained from the first machines which were of about 1000 K.W. capacity each. It was found, however, that about as much steam was used for the re-heating process as was gained by the reheating, and this feature was thereafter omitted. Unless considerable was to be gained, this type of turbine was, of course, objectionable because of its much greater cost, and the greater space occupied, and in addition there were more bearings, couplings, etc., to look after and keep in repair, and as the gain in economy was not great, the two-cylinder type was discontinued after about four-

teen had been built. Some of these earliest machines are now operating at the DeBeers Consolidated Mines in South Africa. It is interesting to note that in developing these two-cylinder turbines, there was incidentally developed and tested both the non-condensing turbine, which is represented by the high pressure cylinder, and the exhaust steam or atmospheric turbine, which is represented by the low pressure cylinder, and although low pressure turbines were not at all generally used until some years afterwards, their practicability and high economy was thoroughly established at this time.

A couple of years afterwards turbines were again being built in a single cylinder in sizes up to 7500 K.W. A typical turbine of this period is shown in Fig. 3. The noticeable change over the early

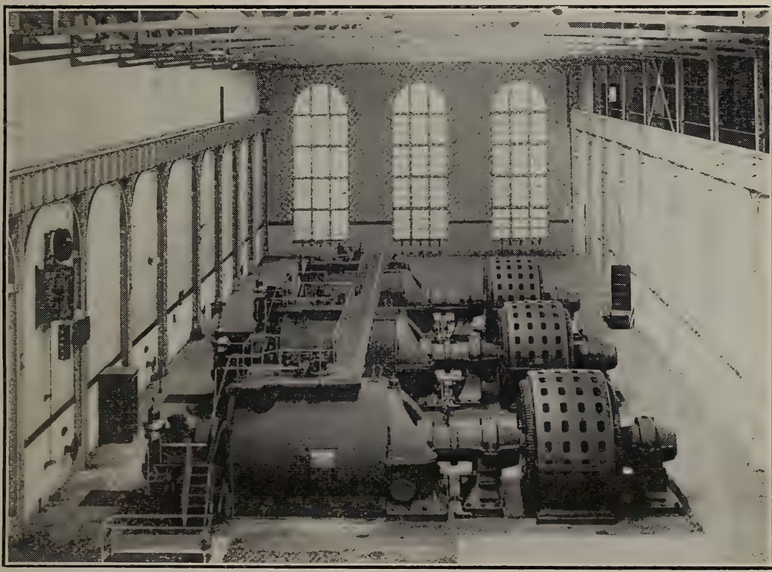

Fig. 5—Three 5,500 KW. turbines in power house of Pennsylvania Tunnel and Terminal R. R. at New York

single cylinder turbine is the absence of the longitudinal ribs and the long cored equilibrium passages; the exhaust being at the bottom and the steam chest located on the top of the cylinder. Fig. 4 shows a 7500 K.W. turbine of this period, and it will be noted that it strongly resembles the smaller size except in dimensions. Fig. 5 shows three of these turbines in the power station of the P. T. & T. Co. at Long Island City, New York.

In 1907 the demand for larger units was becoming very noticeable, and higher speeds were possible because builders had made great progress in developing revolving field A. C. generators. About this time Mr. Westinghouse became impressed with the desirability of building these large size units double flow. It is worthy of note here

that the first Parsons type turbines built were double flow, and were so built because no one knew how to build them single flow; but it must be remembered that these early machines were of small capacity as we measure capacity to-day, and the objection to their being double flow was consequently very great, as blades which would have been uncomfortably short in a single flow machine, were only half that

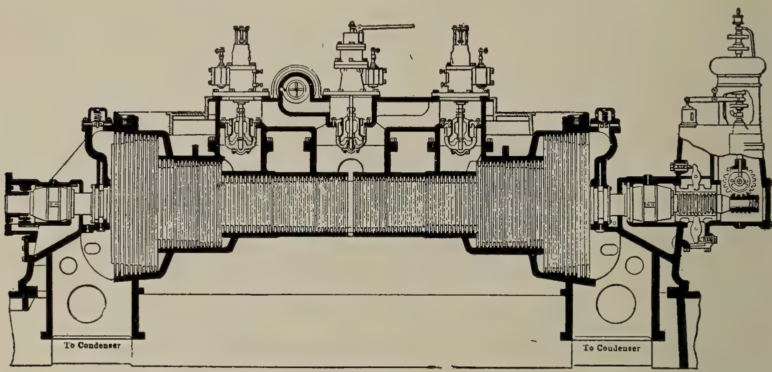

Fig. 6—An idea of what an all-Parsons, high-pressure, double-flow turbine would be

length in a double flow machine. The double flow machine had twice as many rows of blades, so that when suitable steam packing was invented, which would balance the steam pressure on the blade drums, and also compel the steam to flow in one direction, builders

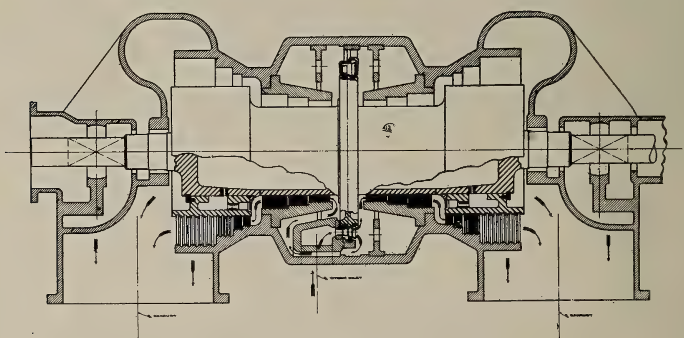

Fig. 7—Section through Westinghouse double-flow turbine

of the Parsons type turbines immediately abandoned the double flow turbine for the single flow. When the demand arose for large units at high speeds the conditions were quite different, for the blades in the low pressure end of the machine had become uncomfortably long, hence the tendency to go back to the double flow construction. The objection to the double flow turbine that it had twice as many rows of blades as the single flow machine still existed. A strictly

Parsons type turbine if built single flow would have the general appearance as shown in Fig. 3. If built double flow, it would appear as shown in Fig. 6. Looking at the double flow machine we notice the extreme length of the high pressure section, and it may be said that this is by far the least efficient section of the turbine and only does about one-fifth of the work. Mr. Westinghouse therefore proposed to substitute for this an impulse element, which occupied very little space, and was probably as efficient as the section of the Parsons turbine which it replaced so that we then had a turbine which is shown diagramatically in Fig. 7, and of which Fig. 8 is a photograph showing the cover turned back. Certain combinations of speed and capacity are sometimes met in double flow turbines

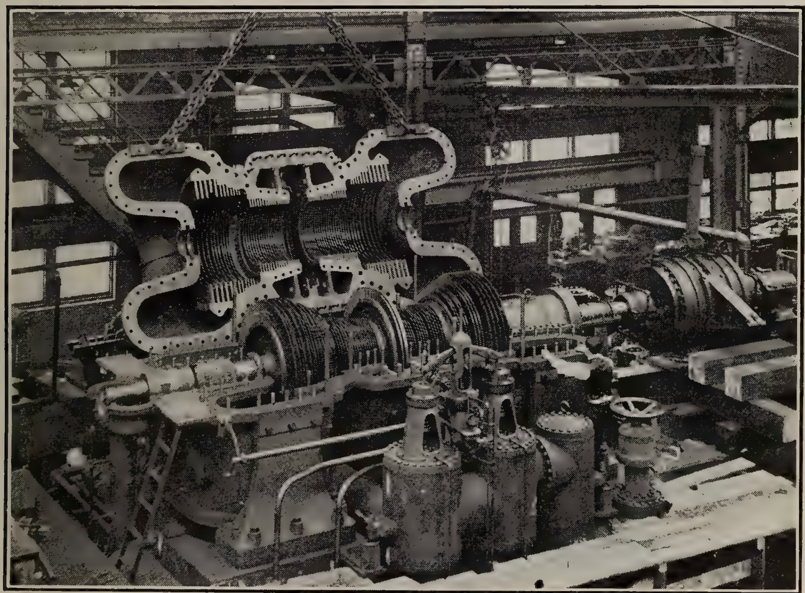

Fig. 8—View of 1,000 KW., 1,800 R.P.M. Westinghouse double-flow turbine, showing upper half of casing turned back so as to expose rotor

where the blades in the intermediate section are too short to be as efficient as they might be. Mr. Westinghouse suggested making this section single flow, and carrying half the steam back through the spindle to the other end of the low pressure section as shown in Fig. 9, using dummies to balance this single flow section, and in this way doubling the length of the short blades.

These turbines, consisting of a high pressure impulse element followed by Parsons blading, the intermediate element being either single or double flow, and the low pressure element double flow, are now the standard practice of The Westinghouse Machine Company for large capacity units. For instance, turbines of 2000 KW. and over running at 3600 R. P. M.; 4000 KW. turbines and over at 1500

or 1800 R. P. M, are built this way. Smaller units than these are best built single flow, excepting low pressure or exhaust steam turbines, and even in single flow machines it is generally considered advisable to substitute an impulse element for the high pressure section for the sake of avoiding high temperatures inside of the main cylinder casting. It will be understood that the steam expanded

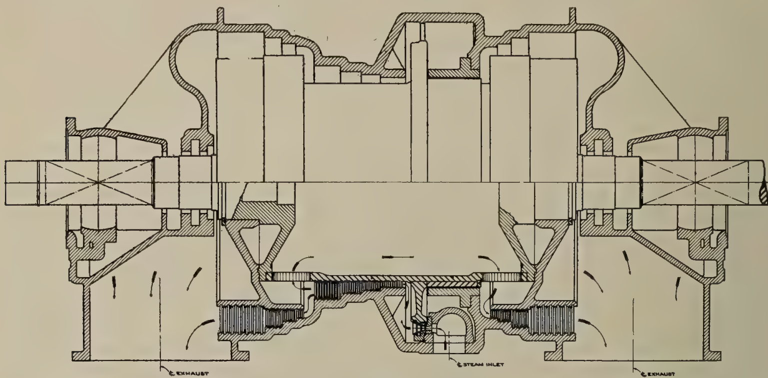

Fig. 9—Section through Westinghouse semi-double-flow turbine

through quite a range of pressures in the nozzles, with a corresponding reduction in temperature, will enter the main cylinder at a temperature, which is not liable to cause the cast iron of the cylinder to grow. The result of combining an impulse element, (which does

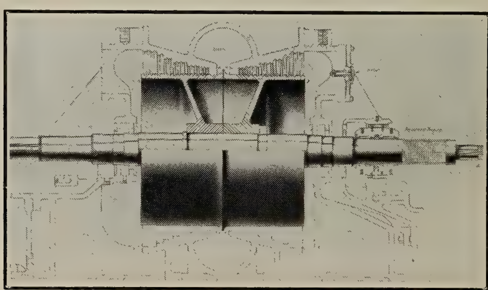

Fig. 10—Section through low pressure turbine

about one-fifth of the work) with Parsons blading (which does about four-fifths of the work) is that we have made a combination of the most efficient portions of the two great types of turbines, and have eliminated the most inefficient portion of each. It also gives us a short and very rugged machine with fewer objectionable features than any pure type turbine yet brought out (except in very occasion cases where a turbine is required to meet some extraordinary co dition).

Prior to 1907 the largest turbine designed to run at 3600 R. P. M. was a 500 KW. but in that year a number of turbines of 1000 KW. capacity were brought out to run at 3600 R. P. M., and in 1909 a

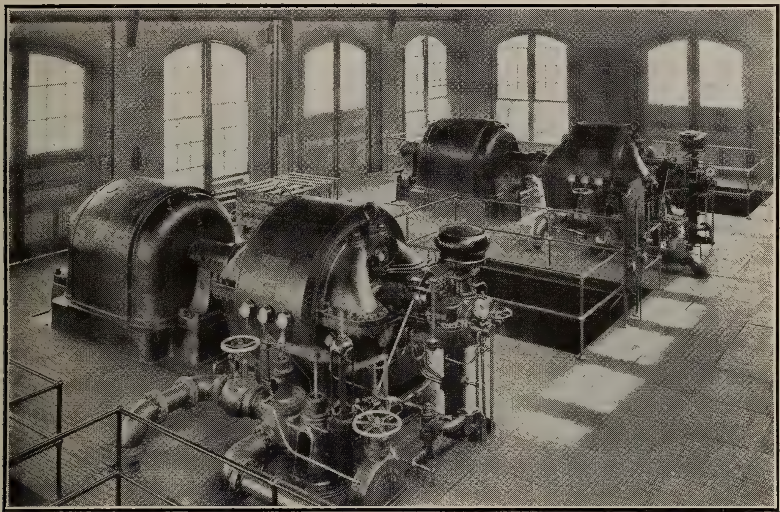

Fig. 11—View showing two 1,500 KW. low pressure turbines at Rankin, Pa.

still further increase of speed was noticeable when 2000 KW. turbines were designed to run at 3600 R. P. M. and a 10,000 KW. unit at 1800 R. P. M. To-day 3250 KW. turbines are running at 3600

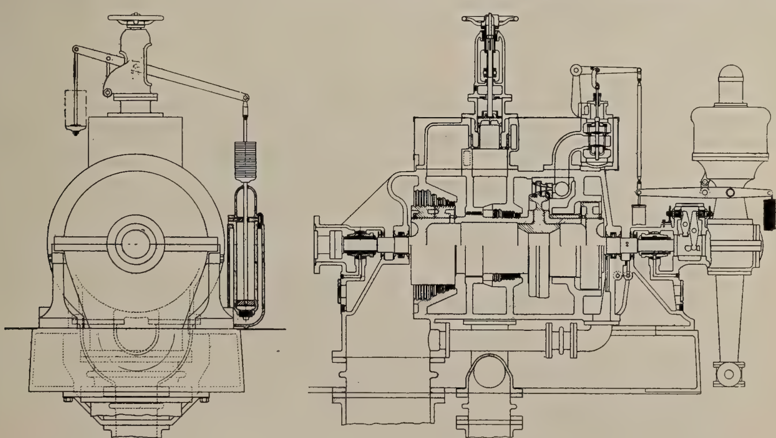

Fig. 12—Section through Westinghouse bleeder turbine

R. P. M., and 15,000 KW. at 1800 R. P. M., and 20,000 KW. at 1500 R. P. M., are being built. The increase in speed has not entailed greater risk in operation, for the construction of rotors and

the method of blade attachment has been so improved that the stresses are not higher than in the old slow speed turbines.

In 1907 low pressure turbines were first built in America. By low pressure turbines we mean turbines to develop power from steam at about atmospheric pressure. The steam may come from the exhaust of reciprocating engines or any other source, and is expanded in the turbine to whatever vacuum is obtainable. A great many of

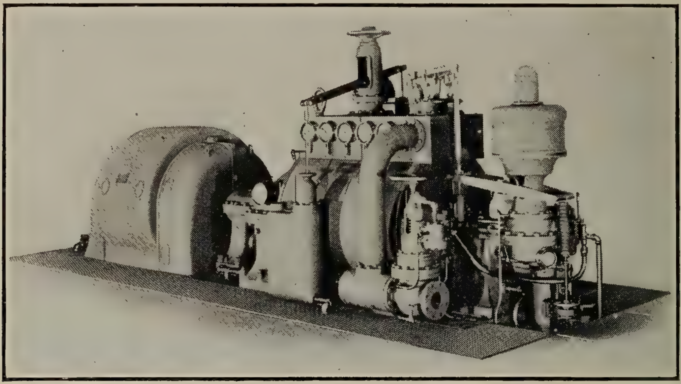

Fig. 13—Exterior view of turbine shown in Fig. 12

these turbines have been built in sizes up to 5000 KW. A typical section through one of these turbines is shown in Fig. 10, and an installation view of the two 1500 KW. turbines is shown in Fig. 11.

A modification of this is found in a mixed pressure turbine which consists of an impulse element followed by the blading of a low pres-

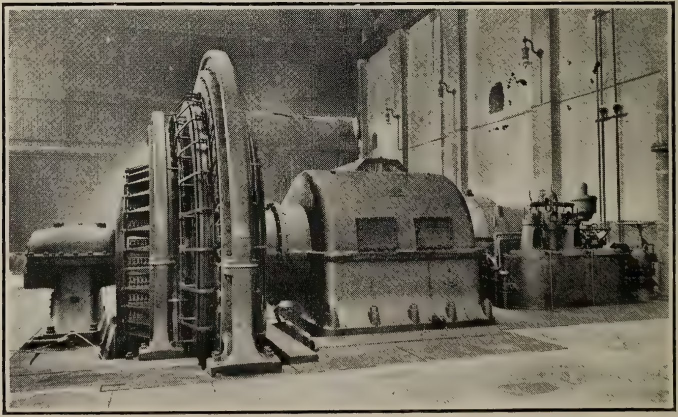

Fig. 14—View of 1,800 P. M. non-condensing turbine driving 3,759 K.W., 180 R. P. M., D. C. generator through Westinghouse reduction gear

sure turbine. These mixed pressure turbines are used in cases where it is desired to develop power from the exhaust of reciprocating engines or any other source, but in which the supply of steam being intermittent, it is necessary to provide for admitting high pressure steam to the cylinder through nozzles which expand it down to about atmospheric pressure, and the velocity energy so obtained is taken up in the impulse blading. The steam then develops further power by expanding through the low pressure blading.

Still another special adaptation of the turbine is found in what is known as the Bleeder Turbine shown in Figs. 12 and 13, which resembles an ordinary condensing turbine, except that provision is made for extracting steam for a heating system from that part of the turbine where the steam has been expanded down to the pressure desired, and equipping the turbine with a valve which automatically passes on to the low pressure blades any steam not required for the heating system.

During the past few years the field of the turbine has been greatly enlarged by the invention of gears which are able to transmit large powers and to reduce the speed of the turbine to that necessary for efficient D. C. generators. A 3500 KW. set is shown in Fig. 14.

Even at this late day it is impossible to predict the trend of future turbine work. The remarkably rapid strides of the past few years have carried the art to a highly advanced stage, but there is no indication that the years to come will be any less productive of developments. The solution of many problems connected with design, materials and manufacture incidental to building the turbines of to-day opens up new fields which seem to be constantly widening. Whereas in 1904, for instance, the design of a 7500 KW. turbine involved great difficulty, it is possible to-day to design a machine of 30,000 KW. capacity, four times the size, with greater certainty of its successful operation and high efficiency.

THE MOOSE JAW WATER SUPPLY

By P. Gillespie, B.A.Sc., A. M. Can. Soc. C.E.

That portion of Alberta and Saskatchewan between the 54th parallel of latitude and the International Boundary comprises nearly 250,000 square miles. It is drained by the Saskatchewan and Assiniboine Rivers, and contains not a single body of water as large even as Lake Simcoe. On a basis of only 20 persons to the square mile, this region would become the abode of five millions of people. The present population is something in excess of 800,000.

When we consider that the great centres of population in Europe, St. Petersburg, Christiania, London, Paris and Berlin, lie north of the 49th parallel of latitude, that the great migrations of history have been westward and northward, that Canada is the last great area awaiting the enterprise and energy of the pioneer, that while in point of population, the United States of America stood 100 years ago where Canada stands to-day, her railway mileage was not until

1857 equal to that of the Canada of to-day, nor her foreign trade as great as that of this country at the present time until the year 1861, it will, I believe, be granted that the growth I anticipate is a very moderate one indeed, and that the problems consequent thereon are really only beginning. One of these is that of water supply.

To the life-long resident of Ontario, with its fine series of inland and border streams and its magnificent chain of great lakes, this special problem of the Western plains will scarcely appeal. In the prairie provinces as indicated above, the scarcity of streams or lakes capable of serving large communities has rendered it both acute and unique. In consequence, it has become the most serious which the growing centres of population in the West are called upon to solve.

The city of Moose Jaw, Sask., is situated on the main line of the C. P. R., some 420 miles west of Winnipeg, and 40 miles west of Regina, the provincial capital. In the language of the surveyor, it lies in Township 16, Range XXVI., West of the Third Meridian. Its present population is approximately 25,000, probably half of whom are dependent directly or indirectly upon railway operation and maintenance for a living. It is surrounded by an excellent agricultural district, and of late years, has experienced a period of growth and prosperity which would be regarded as phenomenal in older districts. In consequence it has outgrown many of its public services including its water supply. Up to a few weeks ago this was obtained partly from a well in the city near the confluence of Thunder Creek and Moose Jaw Creek, which is fed by an infiltration gallery receiving water percolating from the creeks through the soil; and partly from Snowdy Springs, so-called, seven miles distant in a south westerly direction, the supply flowing by gravity through a ten-inch wooden main. Two years ago a deep well was bored at a point adjacent to the present city power house in the hope of locating natural gas. On reaching a depth of some 1200 feet the drilling was temporarily abandoned, a heavy flow of water having been encountered. This water is saline and by itself not potable. In cases of fire it was the custom to pump raw creek water and gas well water into the distributing system, the subsequent draining of which by hand having been relied upon to free the mains from water unfit for domestic use. Of late years the supply has proved quite inadequate to the needs of the citizens, so much so in fact, that at times water was available in the service pipes for an hour only three times a day.

In the spring of 1911, Mr. Walter J. Francis, C.E., of Montreal, was asked by the municipality of Moose Jaw, to investigate the entire situation and advise as to a water supply for this western city. Mr. Francis began his investigation early in May. This involved a study of some ten suggested sources, most of which were found to be impossible because of one or more of three reasons, viz., insufficient quantity, unsatisfactory quality or prohibitive cost. Among the sources investigated were the Moose Jaw Creek, Last Mountain Lake, the Snowdy Springs, the South Saskatchewan River and Sandy Creek, all well-known to residents of Southern Saskatchewan. For the reasons indicated above, all were rejected for immediate develop-

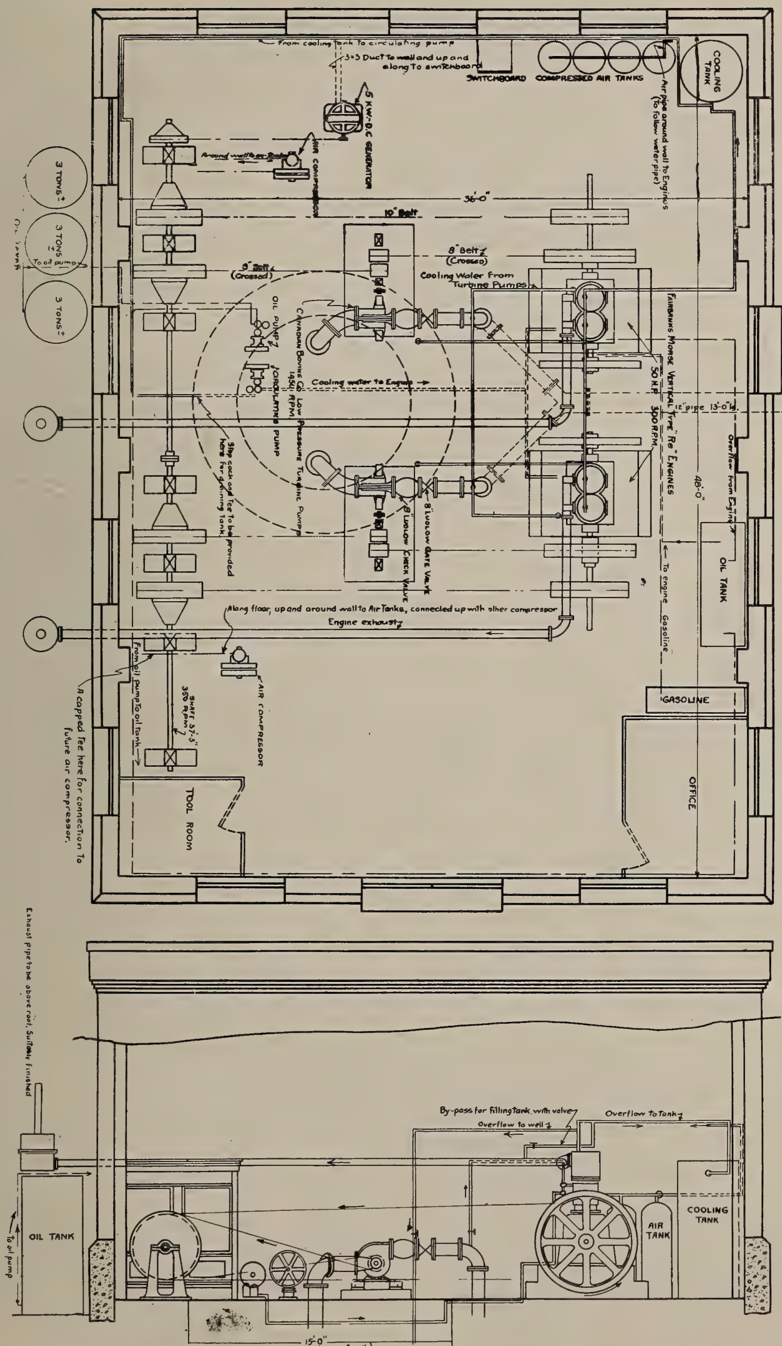

Fig. 1——Plan and Section of the Headworks Pumping Station

ment, save the last mentioned—Sandy Creek—a stream near Caron some 20 miles west of the city, along the main line of the C. P. R.

Mr. Francis' report in brief suggested that the city proceed at once to conserve its then present supply by installing a separate high-pressure fire system in the business district. This would enable the city to cease using the limited domestic supply for such purposes as street watering, most manufacturnig processes and fire fighting. The city was also advised to proceed at once to make a thorough exploration of the valley of the Sandy Creek. The indications at the time the report was prepared were that there was available there one million gallons of water per day. If this by subsequent investigation should be confirmed it would mean that this quantity together with the supply at that time serving the city, would be sufficient for a city of 30,000 people. The ultimate source, it was obvious, must be the Saskatchewan River, in event of the population very much exceeding the limit indicated. Moreover, if the Sandy Creek project were to be developed, much of the necessary installation would become a part of the Saskatchewan development since both sources lie in the same direction from Moose Jaw. The expense involved in utilizing the Saskatchewan necessarily placed it beyond the immediate reach of any single municipality as far distant as Moose Jaw, but a suggestion was made that the city combine with other interests and prepare at once for the use of the Saskatchewan River water at a time not far in the future.

The city council of Moose Jaw, with characteristic western enterprise, immediately voted an appropriation for the investigation of Sandy Creek, which investigation was conducted during the summer months of 1911. Weirs were installed in eight different places on the creek from which daily readings covering several months were obtained. A number of deep test wells were drilled in various places across the wide valley of the creek revealing the presence of a lower supply of water (apparently separated from the upper by an impervious stratum of clay) whose analyses were markedly different from those of the surface water. The knowledge acquired during the exploration tended to confirm the earlier opinion as to quality and quantity and Mr. Francis' firm, Walter J. Francis & Company, were authorized to proceed with the preparation of final plans and specifications, and the supervision of the work. The contracts for the work were awarded during the early months of 1912, and construction was actually begun in April of that year. The water was in use in Moose Jaw before the end of November or within eight months.

The works consist of an infiltration or collecting gallery terminating in a main well over which is constructed a headworks pumping station, a pressure main, a headworks reservoir of 500,000 gallons capacity, a gravity main 96,200 feet long extending from Caron to Moose Jaw, a storage reservoir (in the city) of 2,000,000 gallons capacity, a second pumping station and an elevated tank.

The Infiltration Gallery

The infiltration gallery will consist when complete of 4,000 lineal feet of 20-inch glazed tile laid with semi-open joints in the water bearing sand of the valley of Sandy Creek, at a depth of about 16 feet. Manholes are provided every 800 feet or wherever changes in direction occur. The invert of the pipe has a gradient of 0.4% and is approximately parallel with the natural surface of the ground in which it lies. The lower semi-circumference of each joint is sealed with a cotton sack filled with what was originally dry cement and sand. This is carefully placed in the invert of the bell when the pipe is laid. This sack adapts itself to the irregularities of the tile, while still soft, and later on prevents the admission of sand to the pipe. The upper half of the joint is protected by a depth of one foot of graded gravel which, for the sake of economy, is confined in a cheaply constructed box of spruce lumber scribed to the curvature of the tile. This also prevents the entrance of sand into the interior of the pipe. It will be seen from this that the gallery is intended to drain the surface stream and that it may lower the level of the ground water down to but not below the axis of the pipe.

The laying of this gallery in a water-bearing gravel and quicksand presented some special difficulties. Two parallel rows of 9-inch U. S. Steel Company's interlocking steel sheet piling 18 feet long were driven one on either side of the proposed centre-line of the gallery and distant thereform 2 feet. This was accomplished without special trouble with the aid of a 2¼-inch McKiernan-Terry pile hammer fitted with special driving cap, and by a liberal use of the water jet. The first six feet of depth of excavation was done by hand after which a 6-inch Goulds centrifugal dredging pump was put into service and the remainder of the excavation done thereby, sufficient water to render this operation possible being meanwhi.e admitted to the pit from the creek above. Bulkheads and transverse shoring were placed as the work progressed. The pulling of the piles was accomplished by the aid of a Yale & Towne 3-ton triplex chain block for starting and an ordinary pair of triple blocks with a 1-inch fall and a steady team of horses for the rest of the operation. A generous application of axle grease to both bulb and channel sides of the pile during the driving greatly aided the pulling afterwards. The greatest difficulty met with was the prevention of water coming into the trench from underneath the piling especially where the line led across lagoons as it did in a portion of the work.

The infiltration gallery terminates at its lower extremity in a main well circular in plan, 15 feet in diameter and 29 feet deep and constructed of concrete. An adjunct of this well is a valve chamber through which the water passes on its way to the well and admission to which from the gallery is controlled by a 16-inch gate valve operated from the floor above. This valve chamber is provided with a permanent metal weir enabling the operator at any time to determine the quantity of water being received from the gallery. The excavation for this well was done entirely by the dredging pump. Over the well stands the headworks pumping station.

Headworks Pumping Station

The headworks pumping station is a brick structure 48 x 36 feet in plan, with concrete foundations, base, floor and roof. The mechanical equipment includes two Fairbanks-Morse two cylinder,

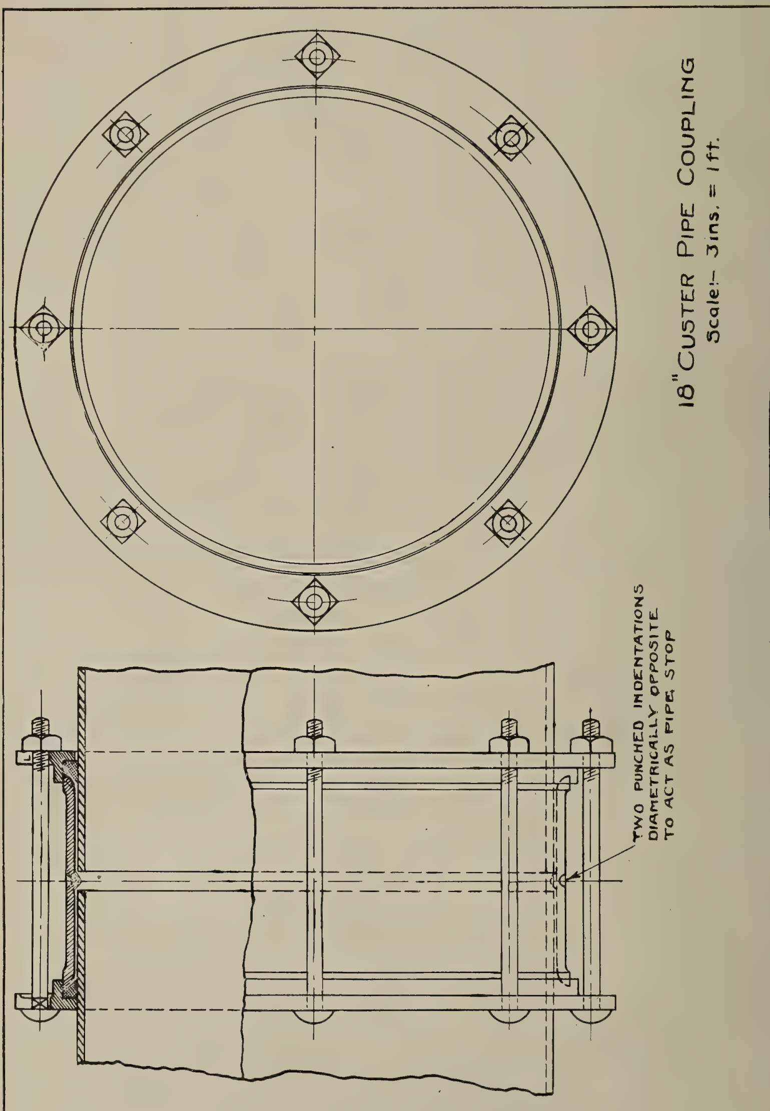

Fig. 2—Custer Pipe Coupling

tour cycle 50 H.P. vertical oil engines belted through a line shaft of two Boving centrifugal pumps each of 600 gallons per minute

capacity. The arrangement is such that either or both pumps may be operated by either engine. The nominal speed of the engines is 300 R. P. M. and that of the pumps 1450 R. P. M. The two discharge pipes join with the 18-inch pressure main in a special wye outside of and below the pumphouse wall. Each pump is protected by a check valve set in the discharge main and priming, when necessary, is done by a by-pass connecting the pressure main beyond this valve with the pump casing. In addition to the engines and pumps there is a 5. K.W. generator for lighting purposes, an air compressor and air storage tanks for starting, and oil and water pumps for fuel and cooling respectively. Ultimately when it is decided to install the deep wells for the purpose of obtaining the water in the low-lying strata of gravel, an air-lift equipment will be employed and the compressor capacity will be increased. Provision for such increase has been made in the lay-out of the station. The usual storage tanks for oil, gasoline and water are provided and complete the equipment.

The Pressure Main

As stated elsewhere, the pressure main has a diameter of 18 inches. It consists of welded steel tubes of thickness ¼ inch and of average length 17 feet. The ends are plain and the joints are made by the Custer method. A sketch of this joint is shown herewith in Fig. 2. The joint mechanism consists of a collar sufficiently large in diameter to slip over the ends to be connected, two followers or gland rings, two rubber gaskets and ten track bolts. The collar is ten inches long and on its interior are two projecting buttons which insure half the collar covering each of the two ends to be connected. A special Custer wrench is used for tightening the bolts. The advantages of this joint are that it is slightly flexible after being laid, that it can be made under water and that a change in direction equal to three degrees at each connection can be secured with 18-inch pipe. With 10-foot lengths it will be seen that a thirty degree curve could be followed if necessary. Experience has shown that if proper care be taken in the jointing, absolute water-tightness can be secured. The specification for laying required that as soon as the pipe was connected up, backfilling to a depth of one foot over the pipe, carefully rammed should be done. The objects of this were to avoid injury to the pipe in case of caving-in, and to prevent the pipe floating in wet situations where water could not enter the free or open ends of the pipe. Part of this pipe had to be laid at a depth of 14 feet and over owing to the regular nature of the ground through which it passed and the advisability of avoiding summits in the profile of the ripe.

Headworks Reservoir

The headworks reservoir is an all-concrete structure circular in plan, 75 feet in diameter and holding when full, 17 feet of water. The roof, which is of the girderless type, is supported by 9 columns placed in three rows of three each. Admission of water to the reservoir and discharge therefrom are controlled by 18-inch gate

valves. The admission valve is protected by an 18-inch check valv The roof is about 8 feet above the normal level of the ground. Back filling against the exterior walls and over the roof slab adequately protects against frost. The concrete was the equivalent of a 1 : 2 : 4 mixture thoroughly well mixed and carefully tamped. No other waterproofing precaution was employed and when after construction, the reservoir was tested full for 24 hours a leakage of less than ¼ of 1% occurred. The difference in level between the normal water in this reservoir and that of the storage reservoir at Moose Jaw is 57 feet. The infiltration gallery, headworks pumping station, pressure main and headworks reservoir were done by day labor instead of by contract, it having been felt that the many uncertainties to be anticipated rendered this procedure advisable.

The Gravity Main

The gravity main from the headworks or Caron reservoir to the city is of 18-inch welded steel with Custer joints of the type already described. The invert is laid at an average depth of 9 feet. To facilitate examination and repairs, it is divided by gate valves into sections averaging one mile and two-thirds in length. The entire pipe is laid on either a rising or a falling gradient, the objects being to permit entrapped air to rise to the summits where air valves are provided. At each air valve there is provided also a poppet inlet valve for the purpose of admitting air whenever a section of the line is drained. Six-inch drains are provided at all depressions and are controlled by six-inch gate valves. These will permit the main to be unwatered in sections when necessary.

Storage Reservoir

The storage reservoir at Moose Jaw has a capacity of 2,000,000 gallons. It is rectangular in plan and is divided transversely by a partition into two equal parts. The 18-inch gravity supply main from Caron divides at a point exterior to the wall and an inlet branch goes to each half. Each branch is equipped with a Mason, float-operated, balanced valve which controls the admission of water. Except at such times as the demand of the city services exceeds the capacity of the gravity supply, this arrangement will insure a full reservoir always. The reservoir is of reinforced concrete throughout, the floor having a thickness of 10 inches. The exterior walls consist of panels 18 feet high spanning between counterforts spaced 9 feet on centres. The partition wall is similarly constructed, except that it is designed to resist a full head of water in either direction. The roof is of the girderless type, supported on columns spaced 18 feet both ways, the slab proper having a thickness of 7½ inches. A five-ply felt and gravel covering overlies the concrete roof and on this, in turn, a filling of two feet of earth is placed.

The Moose Jaw Pumping Station

The Moose Jaw pumping station is of the same general style of construction as the headworks pumping station. Its equipment

consists of two Canadian Boving centrifugal pumps direct connected to two Siemens 35 H.P. motors which receive their power from the supply mains from the city's central power station. These pumps lift the water to the elevated tank a height of upwards of 110 feet. They will ordinarily draw from the storage reservoir but the piping arrangements will permit water to be drawn direct from the Caron gravity main. In addition to this, either pump can draw from either side of the reservoir. Finally the piping system will permit of water being fed (without pumping) from the reservoir or from the gravity

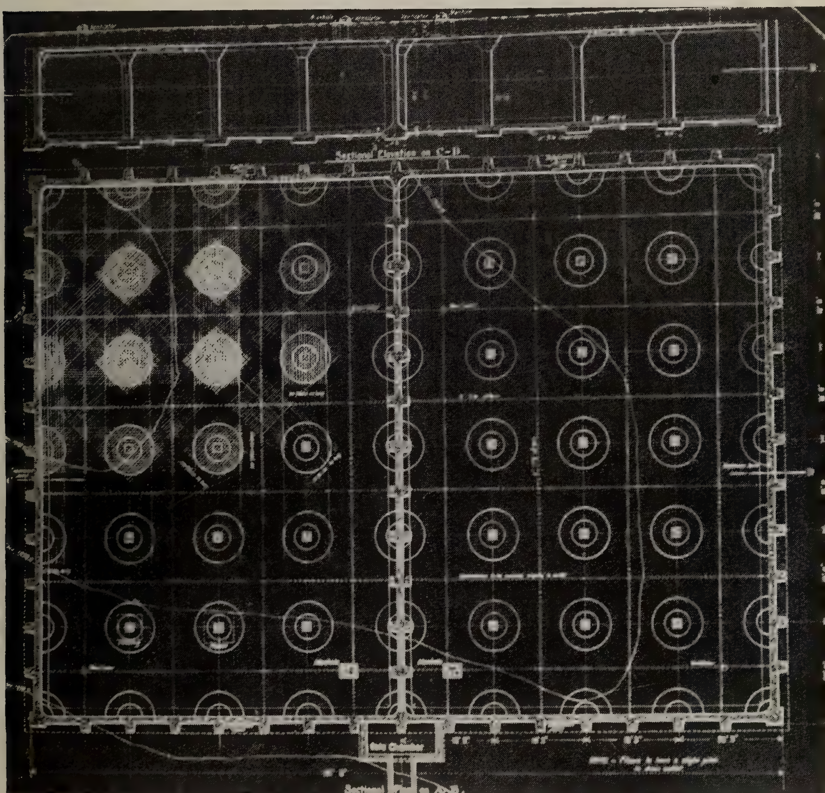

Fig. 3—Plan and Section of Headworks Reservoir.

main into the city's distributing system either of which would give a moderate pressure overall of the city except the highest parts. If desired, the elevated tank may be cut out and the pumps made to discharge direct into the mains. The motors are equipped with Cutler-Hammer switches operated by a float in the elevated tank. This is intended to keep the tank practically full at all times. The pumping station is supplied with a heating boiler with circuits

through the reservoir and the riser of the elevated tank to provide against unusual frost conditions.

The Elevated Tank

The elevated tank is a steel structure of 75,000 gallons capacity, and is carried on four posts. It is provided with a riser 6 feet in diameter. The bottom is elliptical in section. The tank is provided with a mercury pressure indicating gauge and with floats operating the motor switches in the pumping station. The elevated tank, the Moose Jaw pumping station and the storage reservoir stand in close proximity on what is practically the highest ground in the vicinity of the city.

As stated previously, the infiltration gallery, the headworks pumping station, the pressure main and the headworks reservoir were all done by day labor. The Wm. Newman Company, Limited, Maurice S. Holmes, and the Moose Jaw Construction Company Limited, were the contractors for the laying of the gravity pipe line, the pipe itself having been supplied by the National Tube Company through the U. S. Steel Products Company. The storage reservoir and the Moose Jaw pumping station were constructed by the Moose Jaw Construction Company, Limited. George T. Horton, of Chicago, supplied the elevated tank. Drummond, McCall & Company, supplied all valves, fittings and specials. The mechanical equipments at the headworks and Moose Jaw pumping stations were supplied by the Canadian Boving Company, Limited, and the Canadian Fairbanks-Morse Company, Limited.

At the present time the infiltration gallery is laid for only about half its contemplated length, and the system of deep wells across the valley to tap the lower supply has not been constructed. The reason for this is that it was considered best to test out the supply this winter with only part of the gallery in operation. Then, if the conditions require it, the balance of the gallery and the deep wells are to be constructed next season. It is quite likely that the present works will be extended so as to include the whole of the development originally contemplated at the headworks.

Those members of the staff of Walter J. Francis & Company, from the Engineering Faculty of the University of Toronto, were Mr. R. L. Dobbin, '10, Mr. J. C. Murton, '10, Mr. Ross Taylor, '11, Mr. R. E. Green, '11, and Mr. Angus Richardson of the present second year, with the writer in charge of the general supervision of the whole work.

F. H. Chesnut, '08, is resident engineer in charge of the construction of about sixty miles of freight yards for the C.N.R. at Port Mann and also of repair shops, round house, freight sheds and auxiliary plants.

W. G. Worden, '11, is with the Manitoba Hydrographic Survey at Lac du Bonnet, Manitoba.

A. H. Foster, '08, is manager of the Guelph Radial Railway Co.

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EDITORIAL

TWENTY-FOURTH ANNUAL DINNER

The School Dinner has its important place in the calendar cf events pertaining to the University of Toronto. It is to be hoped that all opinions to the contrary are settled for some years to come. The success of the twenty-fourth annual dinner, held on February 13th, 1913, was due, in part, to the conscientious and well organized team work of the members of the Dinner Committee, but largely to their energies being directed along proper lines. It is sufficient to state that the number present exceeded the number arranged for in the plans to such an extent that more would have marred the successful working out of the programme. It remains for next year's executive to lay plans of considerably larger dimensions, if it would maintain the popularity of the policy so ably followed this year by Mr. Ritchie and his officers.

THE U. OF T. CLUB OF NEW YORK

The 11th annual banquet of the University of Toronto Club of New York, was held at the Hotel Astor on Tuesday evening, February 11th. Among the speakers were Dr. H. K. Clark, Dean of the Faculty of Medicine, University of Toronto; Mr. Robert Henderson, past president U. of T. Club of N. Y.; Mr. Ernest Thompson Seton, Mr. Edmund D. Fisher, Deputy Comptroller, New York City; Mr. John A. Stewart, Chairman, 100 Years of Peace celebration, and Mr. Andrew B. Humphrey.

For the first time, the assembly of University men had their annual banquet graced with the presence of ladies, and in all probability this precedence will be upheld in future.

Mr. T. Kennard Thomson, '86, Mr. E. W. Stern, '84, Mr. H. E. Ballantyne, '93, Mr. H. P. Rust, '01, and Mr. T. H. Alison, '92, are among the "School" men who were present.

After the occasion was over the party adjourned to a reception given by the Canadian Club of New York, at the Waldorf Astoria. Mr. Thomson, the President of the latter Club, officiated.

"Toike Oike" Club Dinner

The Montreal Branch of the Engineering Alumni Association, the "Toike Oike" Club, held a dinner on Tuesday, January 28th at Cooper's Restaurant, entertaining the School men who were in the city to attend a convention of the Canadian Society of Civil Engineers. Between 30 and 40 were present. Owing to the absence of the President, Mr. R. A. Ross, '90, the chair was occupied by Mr. Walter J. Francis, '93. With him at the head table were seated Mr. T. Kennard Thomson, '86, C. H. Pinhey, '87, C. H. Mitchell, '92, J. M. Robertson, '93 and D. C. Tennant, '99.

After short addresses had been delivered by Messrs. Thomson and Mitchell, the partakers of the festivities adjourned to the smoker held by the Canadian Society in its new building. Among the men who were present were the following guests from Toronto: T. R. Loudon, '05; T. H. Hogg, '07; H. W. Tate, '09; P. G. Cherry, '11; Others present were W. H. Sutherland, '02; M. C. Hendry, '03; J. P. Watson, '04; A. L. Harkness, '06; C. W. B. Richardson, '07; S. A. Marshall, '07; A. M. Bitzer, '08; F. H. McKechnie, '09; W. D. Black, '09; L. R. Wilson, '09; R. L. Dobbin, '10; H. W. Fairlie, '10; R. M. Walker, '10; H. M. White, '10; T. J. Farrelly, '11; E. H. Niebel, '11; C. A. Meadows, '11; R. O. Stewart, '11, and J. C. Martin, '11.

McGill Engineering Society

Mr. T. Kennard Thomson addressed the Engineering Society of McGill University on Monday, January 27th, the subject of his address being "Caisson Foundations." In the course of his remarks Mr. Thomson referred to his connection with the formation of the first engineering society in Canada in 1885 (one year before the formation of the Canadian Society of Civil Engineers), it being the University of Toronto Engineering Society.

DIRECTORY OF THE ALUMNI

Giving each month, in alphabetical order, the location of a number of the graduates. The entire list will be reviewed in the twelve issues beginning November, 1912.

The graduates will confer a favor by advising us of any and all instances where the list is not up-to-date. Addresses unknown, or no longer correct, are hard to eliminate entirely from our records. If graduates will see that the information given about *themselves* is exactly as it should be, and that that concerning their class mates is also correct to the best of their knowledge, the department will soon be most reliable.

C (*Continued*)

Charlton, H. W., '97, is on the staff of the Experimental Farm, Ottawa, as chemist.

Chase, A. V., '05, whose home address is Orillia, Ont., is with the Department of the Interior, Kamloops, B.C.

Cherry, P. G., '11, is circulation manager of the *Canadian Engineer*, Toronto.

Chesnut, A. W., '10, is in the office of the surveyor-general, Vancouver, B.C.

Chesnut, E. F., '11, is also in Vancouver.

Chesnut, F. H., '08, is at Port Mann, B.C., in charge of the construction of the Canadian Northern Pacific Railway company's shops, freight sheds, etc.

Chesnut, V. S., '09, is on general engineering and surveying with Murdock & Co., at Kamloops, B.C.

Chewett, H. J., '88, is mechanical engineer for the Evans Rotary Engine Co., Limited, Toronto.

Chilver, C. A., '04, is with the Canadian Bridge Co., at Walkerville, Ont.

Chilver, H. L., '04, is also with the Canadian Bridge Co., Walkerville, Ont.

Chisholm, D. C., '10. We do not know in what line of work he is engaged. He is in Winnipeg, Man.

Christie, W., '02, is engaged in engineering and land surveying at Prince Albert, Sask.

Christie, A. G., '01, is assistant professor of steam engineering, University of Wisconsin, Madison, Wis.

Christie, F., '06, is with the Algoma Central Railway in charge of construction.

Christie, U. W., '04, is in Ottawa, Ont., in the Astronomical Survey Branch, Department of the Interior.

Chubbuck, L. B., '99, is with the Canadian Westinghouse Co., Toronto, Ont., in the engineering department.

Clark, F. W., '11, is at Niagara Falls, N.Y. He is in the employ of the International Waterways Commission.

Clark, G. T., '06, is city engineer of Saskatoon, Sask.

Clark, H. J., '11, is in the city at present after spending the summer on engineering work at North Battleford, Sask.

Clark, H. S., '10, is instrument man on the new Welland Ship Canal, at Port Dalhousie, Ont.

Clark, J., '00, was, when last heard from, with the P. & L. E. R. R. at Pittsburg, Pa., as electrician. We do not know his present address or occupation.

Clarke, F. F., '03, is divisional engineer for the Canadian Northern Railway Co. His home is in the city.

Clarke, J. E., '11, is resident engineer for the city of Toronto on the Canadian Pacific Railway grade separation work at North Toronto.

Claveau, J. A., '10, Chicoutini Pulp Co., at Chicoutini, P.Q.

Cleary, F. S., '11. His home is in Windsor, Ont. We have no other address for him at present.

Clement, S. R. A., '05, was with the Hydro Electric Power Commission, but this is not his latest address.

Clement, W. A., '89, is city engineer of Vancouver, B.C.

Cline, C. G., '09, is on the staff of the hydrographic survey, railway belt, Kamloops, B.C. He is spending the winter at his home in Hamilton, Ont.

Clothier, G. A., '99, was, when last heard from, with the LeRoy Mining Co. as engineer at Rossland, B.C.

Coates, P. C., '04, was at Revelstoke, B.C., according to our last information.

Cockburn, J. R., '01, is lecturer in descriptive geometry in the Faculty of Applied Science and Engineering, University of Toronto.

Cockburn, L. S., '10, is a member of

the engineering firm of Wenger & Cockburn, with consulting practice in Regina, Sask.

Code, A. G., '10, is demonstrator in electrical engineering, University of Toronto.

Code, S. B., '04, is town engineer of Smith's Falls, Ont.

Code, T. F., '04, deceased October 29th, 1906.

Cole, C. R., '10, his home is in Woodstock, Ont.; we do not know what he is doing at present.

Cole, D. B., '11, is in charge of repair shops for the Canadian Copper Co., at Copper Cliff, Ont.

Cole, '08, deceased December 31st, 1909.

Coleman, R. M., '10, is at Deseronto, Ont.

Colhoun, G. A., '06, is draughtsman for the Hamilton Bridge Works Co., Hamilton, Ont.

Collett, W. C., '08, is in the city with Collett-Simpson Fibre Tire Works Limited.

Collinson, W. G., '09, has Seeley's Bay for his home address. He was, until recently, with the National Portland Cement Co., Durham, Ont., but is now chemist for the Carborundum Co., of Niagara Falls.

Colquhoun, G. A., '10, is with the Topographical Surveys Branch, Department of the Interior, Ottawa.

Coltham, G. W., '09, is carrying on an engineering and surveying practice at Aurora, Ont.

Conlon, F. T., '02, deceased, July 10th, 1912.

Connell, C. B. B., '07, who until recently was with Mirrless & Watson, Glasgow, Scotland, has no address with us at present.

Connor, A. W., '95, is a member of the engineering firm of Bowman & Connor (H. J. Bowman, '85) with offices in Toronto and Berlin, Ont.

Connor, H. V., '02, is with the Canadian Westinghouse Co., Hamilton, Ont.

Cooch, H. A., '09, is sales engineer for the Canadian Westinghouse Co., with headquarters in Toronto.

Cook, A. S., '11, whose home is in Ingersoll, Ont., is superintendent of the Saugeen Electric Light & Power Co., Southampton, Ont.

Cook, W. A. M., '06, is assistant engineer in the offices of the city architect, Toronto.

Cooper, C., '99, is with the Keokuk & Hamilton Water Power Co., Keokuk, Ia.

Corman, W. E., '09, is chief draughtsman for C. H. & P. H. Mitchell, Traders Bank Bldg., Toronto.

Cornell, C. W., '11, is in engineering and contract work, Exchange Building, Vancouver, B.C.

Corrigan, G. D., '90, deceased May 6th, 1907.

Corrigan, T. E., '05, when last heard from was chief electrician for the Standard Consolidated Mining Co., at Bodie, Cal. We have no address for him at present.

Cory, R. Y., '08, is in charge of the bond department of Baillie, Croft & Wood, Toronto.

Coulson, C. L., '03. His home is in Welland, Ont. We do not know the nature of his professional work.

Cousins, E. L., '06, is harbor engineer for the city of Toronto.

Coulthard, R. W., '99, is general manager of the West Canadian Collieries, Limited, at Blairmore, Alta.

Cowan, W. A., '04, is assistant to the chief engineer of the Canadian Pacific Railway, Montreal.

Cowper, G. C., '07, His home is in Welland, Ont.

Coyne, H., '08, is chief draughtsman for Thomas & Thomas, Racine, Wis.

Craig, J. A., '99, is engaged in civil engineering and surveying at Prince Albert, Sask.

Craig, J. H., '10, is a member of the architectural firm of Craig & Madill, Manning Chambers, Toronto.

Craig, S. E., '04, is engineer for Ritchie & Ramsay, paper manufacturers, New Toronto, Ont.

Creighton, A. G., '06, is a member of the firm of Creighton & Strothers, architects and structural engineers Prince Albert, Sask.

Crerar, S. R., '04, is lecturer in surveying, Faculty of Applied Science and Engineering, University of Toronto.

Crosby, N. L. R., '05, is contracting engineer with McClintic-Marshall Construction Co., Chicago, Ill.

Crosby, T. H., '09, is sales engineer with the Canadian Westinghouse Co., in the Vancouver office.

Crouch, M. E., '11, whose home is in Rochester, N.Y., was with Lang & Ross, Sault Ste. Marie, Ont., when last heard from.

Cruthers, W. M., '11, is with the Canadian General Electric Co., at the Peterborough plant.

Culbert, J. V., '07, is in the engineering office of the Toronto Iron Works.